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Report on the Electrolytic Industries for the Year 2002

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This report, sponsored by the Industrial Electrolysis and Electrochemical Engineering Division of The Electrochemical Society, summarizes published information on production, plant capacities, consumption, demand, trends, prices, raw materials, new technology, and environmental issues in the electrolytic and related industries. The material presented in this report was obtained from many sources and does not necessarily represent the opinion of the authors or their employers.
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Chlor-Alkali Industry

The chlor-alkali industry is now more than a century old. There are three main types of cell technologies in use today: mercury, diaphragm, and membrane. The number of mercury plants has been falling worldwide due to environmental concerns and high energy consumption. Membrane cells are the most energy-efficient and result in higher product purity than diaphragm cells; therefore virtually all recent capacity additions or plant replacements use membrane technology. The chlor-alkali industry remains one of the most power-intensive large-scale industrial processes, using about 2% of the total U.S. electric power production. Caustic (NaOH) and chlorine are produced in 1:1 stoichiometry; therefore demand and pricing for the two products often go in opposite directions. The sum of 1.1 tons of caustic soda and 1 ton of chlorine is called an electrochemical unit (ECU) and expresses the combined product value in dollars per metric ton ($/mt). While caustic can be stored, it is impractical to store chorine in large quantities, therefore the chlor-alkali production rate closely mirrors chlorine demand.

North American industry.—Demand and pricing.—Sagging chlorine demand and falling margins prompted a round of production cutbacks and voluntary maintenance shutdowns in 2001,[1] bringing operating rates down by six percentage points from the previous year and making 2001 one of the worst years in the industry's history. Analysts predicted that already-poor chlor-alkali margins would worsen in early 2002.

The beginning of the year saw caustic soda prices continue to fall steadily, a trend that began in the middle of 2001. In February prices fell by $20-30/ton freight-on-board (fob) for monthly contracts. On the other hand chlorine prices were still steady at this point in time, at about $30/ton fob for the vinyl segment and $60/ton for other segments.[2] Momentum was perceived to be building for a price increase, however, and was expected to happen around the second quarter. The anticipated price increase came as early as February 25th, when OxyChem announced a $30/ton increase in chlorine prices.[3] Olin followed suit with its own announcement for the same price increase the following day.

Chlorine prices continued to recover and rise but even though prices rose to $80-110/ton fob Gulf Coast by April,[4] Steve Brien, director of chlor-alkali and vinyls studies at Chemical Markets Associates Inc (CMAI, Houston), was quoted as saying that market erosion would continue because of falling caustic soda prices.[5] In fact, increased production dragged down caustic prices about $50/ton to $60-90/ton by April.[4] Prices for chlorine continued to escalate in the following months due to tight supply and strong demand, especially in the polyurethane and vinyl sectors, as producers announced hikes of $125-150/ton.[6] At this stage prices for caustic soda also rose slightly, by $10-15/ton.[6]

The price of ECUs rose to $310-345/ECU allowing chlor-alkali margins to enter the black for the first time in 6 months.[7] Further increases in ECU values were anticipated by analysts as long as demand for caustic soda continued to improve. By August, tight caustic soda supply and steady demand, coupled with expectations of further market tightening, prompted a $50/ton price increase, an initiative led by Dow Chemical on August 22 and followed up on by Pioneer, OxyChem, Olin, Vulcan Chemicals and Nexen Chemicals.[8] Pioneer, Olin and OxyChem also announced increases of C$80-85/mt in Canada. The latest increase was not expected to be implemented until October 1, however, because of price protection.

In the third quarter, an anticipated slowdown in the vinyls segment did not materialize, so producers were able to raise production levels steadily to meet demand. At this stage inventory levels were perceived as being comfortable, even low in some cases; PPG was reported to be extremely short on chlorine and OxyChem and Pioneer maintained their 85-95% order control with customers.[9] Supply was particularly tight on the west coast because of strong demand from the bleach segment.[10] It was predicted that the closure of Dow's 400,000 tpy Plaquemine, LA plant in September or October[11] would tighten supply and support the increase despite the expected seasonal slump in demand. In September PPG, OxyChem, and Pioneer announced a $40/ton increase in chlorine prices. Pioneer also announced an increase of C$70/mt;[10] this meant a raise of $175/ton since the second quarter and was seen as pretty hefty by several market players.[12] Although producers expected supply to remain snug through the fourth quarter due to a number of maintenance shutdowns,[10] the increase faltered and was expected to be limited to those customers who did not take on the full $125/ton increase in the third quarter because of contract terms.[12]

At around the same time, producers implemented a $50/ton increase in caustic soda on most customer accounts; however, some larger customers in the pulp and paper segment took on just $25-30/ton of this increase.[12] Some east coast distributors struggling with high inventories balked at the full increase and entered into negotiations with the producers to try to reach some agreement.[12] Chlor-alkali operating rates dropped in the fourth quarter.[12]

Throughout the year, there were also some interesting developments in the spot trade. In early February, spot chlorine prices jumped $60-70/ton.[2] By April prices had shot up to $300-350/ton,[4] due to short supply and rising demand. One producer was quoted as saying that there is simply not an ounce of spot chlorine to be found.[4] Spot prices for caustic soda also increased, by $60-65/ton, raising the price to $80-100/ton from April to July.[6] By the middle of August they had risen again on the wave of the contract caustic price increase, climbing $15/ton in 2 weeks to $95-115/ton.[9] Export prices also moved up about $15/mt, to $100-110/mt.[9] Figure 1 shows the trend in ECU prices during 2002.[13,21]

At the end of 2002 CMAI stated that the average operating rate for U.S. chlor-alkali plants during the year had been 89.9% and predicted that this would be boosted to 93.9% in 2003.[14] The outlook was that nameplate capacity in the U.S. would contract by 1.8% because of shutdowns but demand was forecast to increase by 2.7%.[14] This was reinforced by P. J. Juvekar, analyst at Salomon Smith Barney (New York), who was quoted as saying that chlor-alkali stands out as the only commodity that should improve mate-

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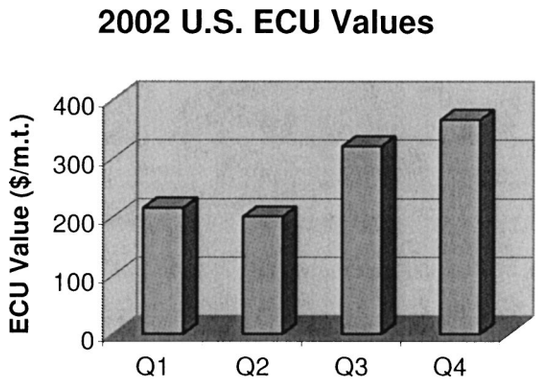

Figure 1. U.S. chlor-alkali price in ECU for the year 2002. A recovery occurred after prices bottomed out in early-mid 2002.[13,21]

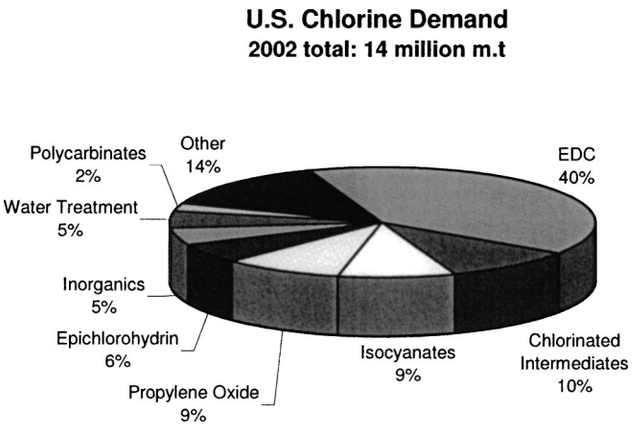

Figure 2. End-use breakdown of 2002 U.S. chlorine demand of 14 million mt.[30]

rially in 2003.[15] Over the next 10 years, the chlor-alkali demand is projected to grow about 1.5%,[1] says Roger Shamel, president of Consulting Resources Corporation (Lexington, MA); margins should, however, rise sharply in 2003 and 2004 as increased demand will not be matched by increased capacity.[1] As usual, however, one of the largest concerns is the prospect of natural gas prices raising power costs,[15] as electricity is the largest cost component of chlor-alkali production.

Plant idling, maintenance shut-downs, and turn-arounds.—Plummeting margins in 2001 forced several producers to rationalize capacity. Atofina Chemicals permanently closed its plant in Portland, OR; Pioneer operated its Tacoma, WA plant at 50%, citing high electricity costs, and Westlake shut down its 122,000 tpy line at Calvert City, KY with an eye to converting from mercury to membrane-cell technology[16] and the intention of reopening in the first quarter of 2002. At the end of the year, analysts warned that more capacity closures were likely until production economics improved.[17]

Early in 2002, OxyVinyls (a 76:24 joint venture between OxyChem and PolyOne) announced that it was closing its chlor-alkali plant in Deer Park, TX indefinitely and would be laying off 200 employees and 70 contract workers.[18] Pioneer followed closely on its heels and announced that it would be permanently idling its plant in Tacoma, WA by the end of the first quarter.[19] Pioneer had planned to ramp up production at that site in October 2001 when a new electricity contract with lower prices came into effect, but crashing chlor-alkali demands brought production to historical lows and did not make the ramping viable. Pioneer claimed that, following the closure, it would meet caustic soda and chlorine requirements from its other plants.[19]

In mid-March, Dow Chemical confirmed that it would replace its diaphragm-cell technology in Plaquemine, LA with membrane-cell technology.[11] The shutdown was intended to coincide with a rise in chlor-alkali production at their plant in Freeport, TX to feed a 500 million lbs/yr Vinyl Chloride Monomer (VCM) expansion at the same site.[11] Although the Texas facility was still down for maintenance in September,[10] the expansion was completed by November.[20] Dow also claimed to be on schedule to shut down 160,000 tpy of chlor-alkali capacity at Fort Saskatchewan, AB by the end of the year.[11] They also announced that although the 1.2 billion lbs/yr VCM plant on the same site would be closed down before the end of 2005, the chlor-alkali plant would continue to operate.[20]

One-week maintenance turnarounds took place at Pioneer's plant in Becancour, Quebec in the second quarter, and turnarounds were planned for Henderson, NV in September and St Gabriel, LA in December.[10]

Other news.—Late in 2001, Pioneer emerged from Chapter 11 protection, but in July 2002 there was a question about whether it would file for Chapter 7 bankruptcy.[21] Its restructuring program has reduced long debt from $600 million to $200 million and brought interest payments down from $55 million per year to $20 million per year. President and CEO Michael Ferris stated that he expected to see more consolidation in the form of joint ventures, alliances, or perhaps even acquisitions, in the future.[21] By September, Michael McGovern had become President and CEO, replacing Michael Ferris.[22]

In July Merrill Lynch analyst Don Carson forecast that Dow Chemical's third quarter earnings would reach $300 million because of pricing momentum in basic plastics and chemicals, including chlor-alkali.[23] Olin reported a loss of $15 million for its chlor-alkali business for the first half of the year.[24] Vulcan materials claimed that its earnings for the third quarter were going to be significantly lower than usual, having been hurt by a slower than anticipated recovery in the industrial sector.[25] During the third quarter earnings conference call Olin reported that chlor-alkali product sales for the year's third quarter were $83 million, a decrease of 11% from the prior year's third quarter.[26]

On August 15 Occidental Chemical Corporation complained to the Federal Energy Regulatory Commission that Conectiv, an energy company in Delaware, was refusing to transfer transmission rights to new power suppliers.[27]

On the morning of October 3 Hurricane Lili forced widespread but generally short-lived outages at a variety of facilities on the Gulf Coast. OxyChem, PPG, and Vulcan Chemicals shuttered operations in Louisiana on October 2, ahead of Lili's landfall.[28]

Maintenance outages at chlor-alkali units that produce hydrochloric acid as a by-product led Nexen Chemicals and Pioneer to announce price increases for hydrochloric acid of $10-15/ton in December, citing tight supply and diminishing inventories.[29]

Figure 2 shows U.S. Chlorine demand in 2002 by product.[30]

European industry pricing.—Europe produces 20 million tons of chlorine and by-product caustic soda each year. These are used in practically every segment of the chemical industry. The 82 plants spread over 19 countries in Europe contribute over €240,000 million yearly to the economy, employ ~40,000 people and indirectly support a further two million jobs in downstream industries.[31]

EuroChlor (Brussels) claimed, in a press release early in the year,[32] that the top five chlorine producers for 2001 had been Germany, France, the United Kingdom, Italy, and Belgium. Executive Director Dr. Barrie Gilliatt was reported as saying that they expected 2002 to be similar to 2001 with pick-up in the latter part of the year.[32] First quarter production of chlorine was 2.2% lower at 2.31 million tons when compared with the same period in 2001.[33] Capacity utilization rates in this quarter averaged 85.3% compared with 88.3% in the first quarter of 2001. By the second quarter chlorine production had started an upward trend, totaling 2,350,550 tons, up

2.2% on 2001 second quarter total. Production in the month of June (773,707 tons) was 4.6% higher than the same month in 2001 (739,751 tons).[33] Capacity utilization for the first half averaged 86.1% against 87% in the same period in 2001.[33] Chlorine contracts, which are negotiated every six months in Europe, were expected to roll back in early 2003 due to production cutbacks.[34]

Caustic had a strong start but suffered some slippage, falling by € 30-40/mt by the fourth quarter. However, a strike at Atofina's 270,000-mt/yr plant at Fos, France[34] as well as some minor production glitches in the region caused supply to become tight. In fact, by the end of the year producers were announcing a price hike of € 100/mt for the first quarter of 2003.[34] Stephen Harriman, director of Harriman Chemsult (London), said that electrochemical units were improving slowly.[34]

Industry news.—Dow claimed in March that it was still on track to upgrade a 1.25 million mt chlor-alkali unit at Stade, Germany by converting some capacity from diaphragm-cell to membrane-cell technology; total capacity would remain unchanged.[11] La Roche sold German chlor-alkali subsidiary LI1-11 Europe (Frankfurt) to private investors.[35] ENI (Rome) appointed several undisclosed banks to find buyers for its Polimeri Europa subsidiary;[36] ENI has set a target to exit the chemical business within the next 2-3 years. ENI has plans to close down its chlor-alkali sites in Assemini some time in 2003.[36] TUI's 50% stake in ECI Electro-Chemie was acquired by Akzo Nobel for an undisclosed amount;[37] making it the sole owner of the company that produces chlorine, caustic soda, and derivatives in Bitterfeld and Ibbenburen in Germany. The company has sales of € 90 million per year.[37] Akzo also operates chlor-alkali units at Delfzijl, Hengelo, and Rotterdam in The Netherlands, and Bohus and Skoghall in Sweden. Over the past three years Solvay (Brussels) has undergone a radical portfolio shift, belying its image as one of the most conservative chemical firms.[38] As the third-largest chlor-alkali producer after Dow Chemical and OxyChem,[38] it is in a strong position to restructure its chlor-alkali business and focus on a smaller number of larger-scale plants.[38] This should boost merchant sales of chlorine, currently accounting for 10% of output.[38] The restructure will also comprise replacement of mercury-cell technology with membrane-cell technology, in order to comply with EU environmental regulations, said CEO Michielsen.[38] Currently around 68% of production is based on mercury cells, 26% on membrane, and 6% on diaphragm technology.[38]

Sustainable technology.—In January 2002 EuroChlor (Brussels) published a sustainability strategy for the chlor-alkali sector, and made six voluntary commitments.[39] By the end of the year a EuroChlor task force, representing a cross section of its membership, had tackled the task of turning them into measurable goals, or sustainability indicators[39] (this is discussed in more detail in the Environment section of this report).

Following a warning by the Food Standards Agency (London) that children beneath the age of sixteen and women wanting to have children should not eat marlin, swordfish, or shark, EuroChlor announced that Europe's chlor-alkali industry was a minor contributor to the problem of mercury contamination in fish.[40] The Industry Association said that although some mercury discharged into the Atlantic Ocean and the North Sea came from mercury-cell chlor-alkali production, the industry's mercury discharges were low and were in the process of getting lower.[41] A report published in September by the European Commission (EC) noted that the conversion to membrane or nonasbestos technology had started and was expected to continue for at least a decade.[42] The preliminary study on which the report was based, found that long-term containment from the phase-out of mercury-cell chlor-alkali plants in the European Union would cost € 180-330 million, in addition to the 3.1 billion it would cost to replace mercury-cell technology with membrane-cell technology.[43] There seems to be no fixed phase-out deadline and it will be up to individual EU countries to decide on a location-to-location basis as to how long such plants may continue.[42] A study commissioned by EuroChlor from independent consultants[44] revealed that an estimated 50% of mercury-cell capacity (compared with base year 1998) is projected to disappear by the year 2010, due to age and/or economics. The remainder will be phased out by the year 2020. According to the EU commission, decommissioning the EU's 47 mercury-cell plants would require the disposal of 10,000-12,000 mt of mercury.[43] Although it does not favor any specific option it did highlight containment in a sealed landfill as the most environmentally sustainable option, even if this would not provide a complete solution.[43] The industry, however, favors the re-use of mercury for legitimate applications over containment, said EuroChlor director Barrie Gilliart.[45] Uses include small-scale gold processing.[43]

Other news.—Effective July 1 European suppliers of the chlorinated solvent trichloroethylene (TCE) were required to apply a new hazard warning label to their products, along with the Risk Phrase ''may cause cancer.''[46] The change followed an EU decision to reclassify TCE from a Category 3 to a Category 2 carcinogen under the Dangerous Substances Directive. This brought TCE into the scope of more stringent worker health protection rules.[46] As a result, merchant sales declined by 11% to 66,000 tons[46] (the greatest reduction in five years). This led the European Chlorinated Solvent Association (ECSA) to commission a three-year epidemiological study of French metalworkers from the University of Lyon.[46] If the results do not confirm previous findings, the EU will be asked to reconsider its reclassification.[46]

Two important appointments were announced in April; Veronique Garny, a Belgian national, was appointed Science Director of EuroChlor,[47] succeeding professor Andre Lecloux who retired after having held the post since April of 1995. Lorain McCann, a UK national, was appointed chairperson of the ECSA, succeeding Marc Winet of Dow Europe.[48]

In mid-August Unipetrol (Prague) claimed that the flooding of the Elbe River had caused yet another chlorine leak from a chlor-alkali plant at the Neratovice site of the company's Spolana subsidiary.[49] Greenpeace was reported as saying that the leak could put mercury into the river, as the site contaminated with mercury had been under water since August 14.[49] By the following week, Unipetrol had replaced CEO Radoslav Vek with Miroslav Kulika.[50] Jan Papez, head of the government committee investigating the flood damage, compared the damage from the leaks to a mini-Chernobyl.[50] Production started up again at the site in December, and there was concern that the restart would further weaken European PVC prices, which were already softening due to seasonal demand slowdown.[37]

Other world industries.—Although economic growth was very uneven in Asia, the economies in the region fared better than was anticipated in January, and gross domestic product (GDP) grew by 5.6%.[51] China's 114 major chlor-alkali enterprises generated 41.5 billion Yuan (~$5 billion) in the first 11 months of the year,[52] up 12.5% year-on-year, and their sales/output ratio reached 98%, according to the China Chlor-alkali Industry Association.[52] The caustic soda output of the enterprises amounted to 8.1 million tons, up 12%.[52] The rise in China has encouraged investment. According to Stephen Harriman of Harriman Chemsult (London) more resources have been invested in covering the Chinese market during the year. He was quoted as saying that region is driving the global perspective on polyvinyl chloride.[53]

In September German Chemicals firm BASF was given the go-ahead by China's central government to build a giant chemical plant in Shanghai to benefit from China's consumer boom.[54] BASF heads a consortium of foreign firms, which will form a joint venture with Shanghai Chlor-alkali to build the $1.2 billion factory.[54] Shanghai Chlor-Alkali will provide 30% of the total investment,[54] while BASF and other consortium members, including U.S. firm Huntsman Polyurethane, will provide the rest. The Shanghai plant, which should take around 2 years to construct,[54] will be BASF's second biggest investment in China, dwarfed only by its project to build the country's ethylene cracker in Nanjing.[51] Shanghai Chlor-Alkali also

intends to set up joint ventures to construct a 350,000 mt/yr caustic soda facility and up to 400,000 mt/yr capacity EDC and VCM plants.[55] Caustic soda will be supplied to the MDI/TDI joint venture, as well as Bayer's proposed 200,000 mt/yr polycarbonate plant. The EDC plant will consume chlorine generated by the MDI plant.[55] Nichimen and Chisso have won a contract to expand Shanghai Chlor-Alkali's PVC plant from 280,000 tpy to 350,000 tpy, with completion slated for October 2003.[56]

Japan's economy did not fare as well. Asahi Kasei claimed[51] that the sales in the chlor-alkali category had dropped sharply due to the reduced sales volume, reflecting weak market demand and deteriorating market prices for chlorine products (notably vinyl chloride). Sales volume for caustic soda also remained sluggish. The rise of China, however, became more of an opportunity than a threat to Japan's chemical industry.[51] Mitsubishi Chemical recently announced that it would actively seek investment projects in basic chemicals in China.[51] A project to produce ammonia and other chemicals from fully-recycling waste plastics is being constructed by Showa Denko in Kawasaki.[57] The project will cost $7.4 billion Yen. Subsidies of 3.7 billion Yen have been granted by the Japanese government and Kawasaki City.[57] The project is to be completed by March 2003. Chlorine resulting from PVC in the waste stream will be neutralized with alkali and used to produce chlor-alkali.[57]

Asahi Glass is concentrating on its fluorochemicals business, including membranes, and withdrawing from the cell portion of its electrolytic cell business.[58] More details are included in the Fluorine and Fluorinated Gases section of this report.

Chemfab Alkalis of New Delhi, India, a Singapore-held company, was awarded a prestigious Three Leaves Award, given to environmentally clean firms in the caustic chlorine sector. This award was awarded by India's Center for Science and Environment (CSE). Chemfab's plant in Pondicherry has an annual turnover of around Rs.7 million (~$266 million); it was named the cleanest caustic soda plant in the country.[59]

Sitara Chemical Industries (Faisalabad, Pakistan) issued bonds worth $6 million to partly finance the expansion of its chlor-alkali plant at Faisalabad.[60] It claims the rest of the financing will be provided from cash flow. Asahi Kasei will supply its proprietary membrane technology for the expansion and the project will increase caustic soda capacity at the plant to 52,000 mt/y.[60] Sitara Chemical also commissioned a chlor-alkali plant near Lahore, Pakistan, with a capacity of 200 tpd caustic soda. The $6 million plant will use membrane cell technology supplied by Asahi Kasei.[61]

Taiwan's economy rebounded and is projected to continue to do so in 2003. Chemical production increased by 10% overall and Formosa Plastics, the island's leading maker of polyvinyl chloride, expected to improve its pretax profit for the year by 43%.[51]

Hydrochloric Acid

The North American market for hydrochloric acid, also called hydrogen chloride (HCl), went from oversupply at the beginning of the year to balanced and even tight conditions at the end of 2002. Supply-side reductions, price increases, and tightening of the chlorine market (Cl_2 is a raw material for HCl production) as well as maintenance outages at chlor-alkali units that produce by-product HCl, led to a series of $10-15 per ton increases starting from $65/ton at the beginning of 2002.[29] Price increases began with Vulcan Chemicals in May ($10/ton),[62] followed by Reagent Chemical & Research Inc.[63] and Olin Corp.[64] ($10/ton); a second round of increases was conducted by Reagent[65] and Vulcan[66] ($15/ton). Nexen Chemicals ($10/ton) and Pioneer ($15/ton) followed suit in December,[29] as well as Gulbrandsen Technologies Inc. ($15/ton)[67] and BASF ($15/ton).[68] Prices were forecast to rise further in 2003 as HCl production capacity was expected to decrease.[68] The market has both spot and contract material, and contracts have usually been negotiated annually. Similarly, in Japan, prices were expected to rise in 2003, as falling demand for caustic soda seemed to have bottomed out at the end of 2002 and global demand was expected to increase.[69] The largest merchant marketer of HCl is Reagent, according to SRI International.[70]

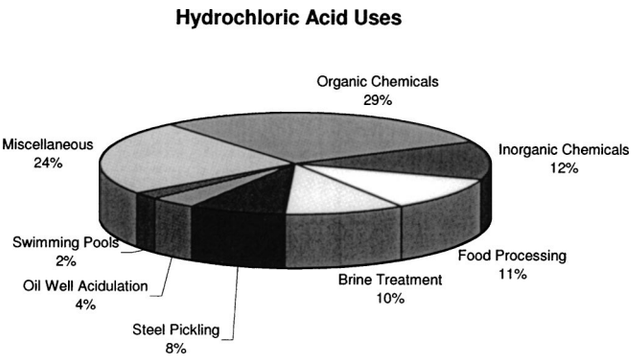

Figure 3. Uses for hydrochloric acid, excluding EDC production.[72]

The U.S. experienced local variations in the HCl market, with oversupply in the Gulf area and tight supply in the northeast. In the northeastern region, Metachem Products LLC's 33,000 short-ton (st) plant in New Castle, DE was permanently closed, and Sasol's Baltimore, MD facility, where HCl had been produced as a by-product of linear alkyl benzenes, was converted to a process that does not produce HCl, taking roughly 100,000 st off the market.[68,70] The Environmental Protection Agency (EPA) has set a phase-out deadline of January 1, 2003 for the production of hydrochlorofluorocarbon, HCFC-141(b). As a result of the EPA ruling, HCl production is expected to fall.[68]

About two thirds of total HCl production originates in vinyl chloride monomer (VCM) production, where it is a by-product. However, about the same amount is used for the production of ethylene dichloride (EDC), which usually occurs within the same plant. For example, Dow Chemical, the world's largest producer of Chlorine, VCM, and EDC, recovered and recycled 4 billion pounds of HCl in 2001.[71] Only about one fifth of all hydrogen chloride is traded on the merchant market.

HCl burners are a convenient way to produce HCl on demand by burning chlorine with hydrogen. The economics of this process depends mainly on chlorine and hydrogen prices. In times of high chlorine prices, such as in mid-2002, HCl production from burners is cut back in favor of selling higher-valued chlorine.[68]

Main uses of merchant market HCl are in the production of organic chemicals and calcium chloride, the food industry, brine treatment, in the steel industry (pickling), and oil and gas exploration, where acid is consumed in the drilling process (see Fig. 3).[72] Overall, HCl demand for these applications is increasing (see Fig. 4).[72]

Fluorine and Fluorinated Gases

Much of the activity in the fluorine industry was driven by environmental concerns and the resulting shift from perfluorocarbons (PFC) and hydrofluorocarbons (HFCs) to gases that have less effect on the earth's atmosphere and resulting climate change. As a result of the 1987 Montreal Protocol agreement, and individual country regulations controlling new production, consumption and trade of CFCs and HCFCs, the global fluorocarbons market continues to undergo a major transformation toward greater use of more environmentally benign HFCs and nonfluorocarbon alternatives. Modest growth (2.5%) is expected in the major sector, refrigeration; strong growth (6%) for the second largest sector, polymer precursors; and constriction (−10%) in the third largest sector, foam-blowing. Aggregate annual demand is forecast at 1% through 2005.[73]

In April, Europe's fluorinated gas producers announced to the European Commission their intention to reduce emissions of global warming gases as a means of averting commission legislation. Two industry groups, The European Fluorocarbon Technical Committee (EFCTC, Brussels) and the European Partnership for Energy and the

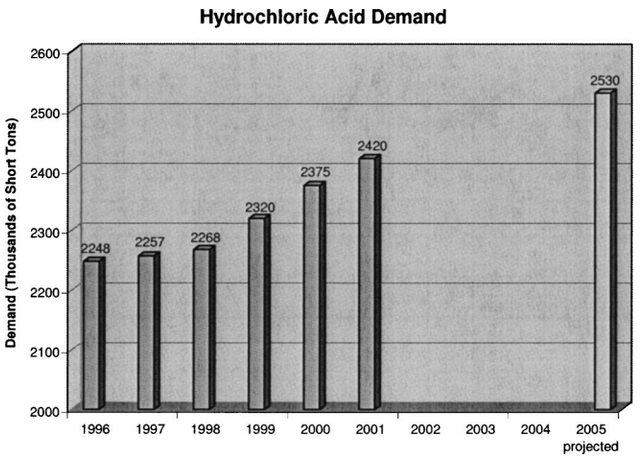

Figure 4. Demand for hydrochloric acid has been increasing steadily in recent years and is projected to rise further.[72]

Environment (EPEE, Brussels), held a meeting in Brussels in April where they agreed to jointly develop industry initiatives to control emissions of fluorinated gases. The meeting followed the commission's announcement that it plans to control the production of fluorinated gases as part of its Kyoto Protocol commitment. Manufacturers of fluorinated gases are concerned that the commission's initiative would lead to a phase-out of fluorinated substances such as HFC and PFC.[74,75]

In October the German government unveiled plans to reduce the consumption of HFCs, PFCs, and sulfur hexafluoride (SF_6). The substitution of these gases would reduce greenhouse gas emissions by the equivalent of 13 M tpy carbon dioxide. Industries are being urged to substitute these gases with benign alternatives voluntarily or face legislation. A response to the proposals was expected before the end of October 2002.[76]

Ineos plans to expand its activities in fluorine chemicals in the pharmaceuticals sector, where it is already a leading supplier of hydrofluoroalkanes (HFAs) for medical propellants. The company has two plants. One site is at Runcorn, northwest England. The other is a joint venture with Great Lakes Chemical Corp. in Arkansas. Both sites have been certified cGMP compliant by the Food & Drug Administration (FDA) and the UK's Medicines Control Agency (MCA). The units make HFA 134a and 227ea as replacements for chlorofluorocarbons (CFCs) in metered dose inhalers for asthma sufferers. They are stand-alone facilities for the manufacture of a single product to avoid cross-contamination of one propellant by another.[77]

Honeywell Specialty Materials had sales of $3.3 billion and profits of $52 million in 2001 (1999: $439 million). A new HFC245a plant is about to go onstream within Honeywell's $600 million per year fluorine products business. This product will replace HCFC141b. The newer blowing agent gives Honeywell a 20% margin, compared with 10% for the older one. Sales in the specialty chemicals unit, which includes electronic chemicals, pigments, and reagents, was $470 million in 2001, with operating margins at 18%.[78]

Honeywell's fluorine products business has opened a world-scale plant in Geismar, LA, for the production of Enovate 3000 (hydrofluorocarbon-245fa), a blowing agent for polyurethane and polyisocyanurate foams. HFC-245fa, also known as 1,1,1,3,3 pentafluoropropane, is a nonflammable and nonozone depleting liquid. It will replace HCFC-141b, a widely used blowing agent that is scheduled to be phased out in the U.S. on January 1, 2003 and in Europe and Japan during the 2003-2004 timeframe. Honeywell is the only large-scale producer of HFC-245fa. The company broke ground for the new plant in April 2001 and started it up in August of 2002. The new plant represents a total investment of $130 million, including R&D and construction.[79]

Fluorocarbon manufacturers are working with the polyurethanes industry to replace CFCs and HCFCs with nonozone-depleting blowing agents and technologies. Under the Montreal Protocol, the U.S. and other developed countries have already replaced CFCs in foam blowing. The main replacement for CFC-11 in foam blowing, HCFC-141b, is also near the end of its allowed life span (see above). Further global reductions in ozone-depleting chemicals, required under the Montreal Protocol, will begin on January 1, 2004.

The rigid foam industry annually consumes roughly 130 million pounds of HCFC-141b in North America and 250 million pounds globally, according to Honeywell. Air Products is addressing the replacement of HCFC-141b by introducing additives to facilitate the use of HFC-134a, HFC-245fa, hydrocarbon, and water blowing technologies.[80]

As mentioned in the Chlor-Alkali section of this report, Asahi Glass is accelerating efforts to develop its fluorochemicals operation into one of its core business segments. In parallel, the firm is downsizing and revamping its chlor-alkali operation, with a view to redefining the operation's role into that of supplying raw material for fluorochemicals production. Efforts to strengthen the firm's fluorochemicals business overseas are also underway. Asahi Glass purchased ICI's fluororesins business in 1999 and acquired U.K.-based F2 Chemicals in 2000. These moves have enabled the company to expand into the downstream of fluorochemistry, such as transparent resins, pharmaceutical intermediates, films, and ion-exchange membranes, where the firm has a technological edge. In addition to this globalization program, the Tokyo-based firm intends to develop a closer link in Japan between its chlor-alkali production and fluorochemicals operation. Asahi's Chiba Prefecture-based plant, with its chlor-alkali output and locally produced natural gas, reportedly offers the most promising opportunity to realize this scheme. Using natural gas-derived high-purity methane and chlorine, the plant produces chloromethane as a raw material for its hydrochlorofluorocarbon (HCFC)-22, ethylene tetrafluoride, and other fluorine derivatives. The firm aims to expand its product lineup and enhance its competitiveness by optimizing this start-to-finish production process.[81]

Ozark Fluorine Specialties has licensed technology developed by a University of Idaho chemistry professor for the production of electrophilic trifluoromethylating reagents. The technology facilitates the introduction of fluorine-containing groups.[82] Applications are expected in the chemical, agrochemical, and pharmaceutical industries.[83] Ozark will expand manufacturing at its Tulsa, OK, facility by over 50 fluorine cells in its first foray into the production of fluorine for value-added specialty chemicals. Ozark's primary business has been anhydrous hydrogen fluoride (HF). The new capacity will allow Ozark to develop specialty gases for the electronics and semiconductor industries. A partnership to provide this market with enhanced supply of specialty gases was sought. The joint venture partners would install and operate chemical production units requiring elemental fluorine.[84]

Synquest Laboratories of Alachua, FL that manufactures around 2000 fluorine compounds for use in R&D and custom synthesis with sales of around $3 M, has been acquired by Central Glass of Tokyo, Japan. Central Glass has begun manufacturing fluorinated fine chemicals at a new plant in Ube, Japan.[85] F-Tech has embarked on a project to expand capacities at its multipurpose fluorine gas plant and organic synthesis facility. Both are located at its Nanyo site in Yamaguchi Prefecture. Custom synthesis capacity will be approximately doubled once construction work is completed, and as a result, the company is aiming to increase the business' contribution to 40% of overall sales. F-Tech is part of the Tosoh Group and a specialist in fluorine chemistry. The company is particularly well known as a leading player in trifluoroethanol, a product for which it commands a 60% global share. This product is used as an anesthetic and agrochemical raw material. In its specialist field of fluorination, F-Tech boasts a line-up of six types of fluorinating agents that are employed in a diverse menu of fluorination processes including stereoselective electrophilic fluorination and fluorination technology

using fluorine gases in which cost merit is brought to the fore.[86]

DuPont Fluoroproducts is planning a joint venture with China Nuclear Honghua Specialty Gases Co. involving the chamber-cleaning gas Nitrogen TriFluoride (NF_3). NF_3 is used in the semiconductor industry to clean chemical vapor deposition (CVD) chambers. The venture, majority owned by DuPont, will build an NF_3 plant in China by mid-2005 using DuPont technology. DuPont already markets output from an existing Honghua plant.[87] DuPont said it planned to end merchant sales of anhydrous hydrogen fluoride (HF) at the end of 2002 and sell its HF transportation assets to Quimica Fluor (Matamoros, Mexico), a maker of HF and other fluorochemicals. Terms were not disclosed. DuPont said it will continue to produce HF at LaPorte, TX for its own use as a fluorochemical feedstock. HF is vital to DuPont s fluorochemical operations, but the merchant market activity has always been a small, nonstrategic part of the business. The merchant market accounted for 10% of DuPont's HF production, the company said; it did not disclose capacity or sales figures. DuPont will continue to be a net purchaser. Quimica Fluor produces HF at Matamoros. Honeywell and Solvay are the only other HF producers in North America.[88]

Capacity for the manufacture of fluorine-based light-emitting polymers is to be expanded at Midland, MI by Dow Chemical's Advanced Electronic Materials business. The multi-million dollar expansion will take place in two phases, the first being completed in 4Q 2002 and the second in 3Q 2003. Polymers that emit light in the blue, green, and red regions of the visible spectrum will be produced following the expansion. A blue material was to be commercialized by Dow before the end of 2002.[89]

Researchers at Rice University (Houston) and the Russian Academy of Science's Institute for High-Pressure Physics (Moscow), say they have developed a way to put fluorine into carbon nanostructures, such as nanotubes. The technology should significantly lower the manufacturing cost of these structures, and open the door to production of derivatives with novel properties, the researchers said. The process involves fluorination at high temperature and pressure. Carbon nanostructures are inert and chemically stable, which makes producing derivatives difficult. The addition of fluorine provides a chemical ''handle'' that gives chemists the ability to attach other molecules. Unlike pure carbon nanotubes, they are all soluble in organic solvents.[90]

Potash

Potash comprises potassium salts that are water-soluble, including potassium chloride, potassium sulfate, and potassium nitrate. They are employed most commonly in the agricultural segment as fertilizers and animal feed, although they are also used as raw material by the chemical, drilling, pharmaceutical, nutritional, and photographic industries. The North American potash market is a mature one, although there is some debate as to whether it is generally balanced or whether there is overcapacity.[91] Industry sources were anticipating 2-3% growth this year; export markets were also showing an increase in demand, especially China.[91] An attempted $6 per short ton (st) increase proposed in February did not hold. This increase was not effective due to late-starting spring planting season as a result of widespread rains in the Midwest, high inventory levels, and sluggish demand.[91] However, shortly afterwards, Potash Corp. of Saskatchewan, IMC Global, Agrium Inc., and others increased potash production prices by $4 per st, effective mid-April.[91]

Plant news.—Tenderlo Chemie announced that it would be converting a mercury-cell chlor-alkali plant to a facility producing 150,000 tpy caustic potash; the conversion is supposed to be completed by the year 2004.[92] Israel Chemicals (ICL) stated that it intended to carry through on its deal to acquire Anglo-American subsidiary Cleveland Potash for the sum of $45 million. Cleveland Potash is a leading potash producer and had sales of $90 million in 2001.[93] Plans to produce 1 million tpy potassium chloride fertilizer from Chaerhan Salt Lake in China are being developed by Qinghai Salt Lake Potash Co. of Germu in China.[94] The company currently produces 300,000 tpy potassium chloride. Trial production is set to begin in 2003, with completion expected in 2006. Most of the potash will be exported.[94] Enterprise Miniere et Chimique (EMC, Paris) plans to go ahead with the closure of all operations at its potash mining subsidiary Mines de Potasse d Alsace by 2004.[95] Potash Corp. plans to restart its 790,000 tpy plant in White Springs, FL in 2003, increasing supply by 50,000 tpy.[96] In late summer, Engro Chemicals commissioned a $10 million, 100,000 tpy potash, nitrogen and phosphates fertilizer plant at Daharki, Pakistan.[97] The unit will be expanded by a further 20,000 tpy by the end of the year.[97]

Other news.—IMC Global is in the process of completing a two-year restructuring that will clean up its portfolio and generate proceeds to ease its debt. With lower debts and greater concentration on its potash (and phosphates) business, IMC is poised to take advantage of the upswing in the fertilizer market.[98] Dead Sea Works (DSW) issued a contract to U.S. Filter to provide a hot-leach crystallization system to produce 1.3 million tpy potassium chloride.[99] While some of the equipment will be used to upgrade the company's potash plant at Sodom, Israel, which produced 2.9 million tons in 2001, the rest will be used to expand capacity. The new crystallization process is to be installed by 2003.[99] A 1.3 million ton contract to supply potash to China was won by Canpotex of Canada[100] for shipment through July 2002. 55.65% of Canpotex s potash requirement is supplied by Potash Corp, 34% by IMC Global and 9.38% by Agrium Inc.[100] A 26% stake in Arab Potash Co (APC) of Amman in Jordan is to be sold to an overseas company for about $117 million. The deal, to be overseen by HSBC, will reduce the Jordanian government's stake in APC to 26.8%. Potential buyers include Potash Corp, Mitsubishi Corp and Kali und Salz.[101] Israel Chemicals restructured most of its fertilizers subsidiaries to create a new unit, ICL Fertilizers (Beer Sheva, Israel); these included potash producers Dead Sea Works (Beer Sheva), Iberpotash (Barcelona, Spain), and Cleveland Potash (Saltburn, UK).[102] Occidental Chemicals Asia plans to work on expanding sales of caustic potash and potassium salts.[103] The company expects to step up developments of new applications such as for plasma display panels (PDP). In a bid to diversify its business, the company will develop potassium salts into a pillar second to its main business of ethylene dichloride.[103] The company is the Japanese marketing arm of Occidental Chemical (U.S.).

Calcium Chloride

Calcium chloride is noted for its versatility. It has unique properties that make it ideal for maintaining unpaved roads and strengthening new roads for construction. The anhydrous compound is commonly used as a drying agent, absorbing water till it dissolves into liquid; this characteristic makes it effective in settling road dust. Moreover, calcium chloride's ability to give off heat as it melts makes it particularly effective as a de-icer. It is also used to treat water in aquariums and as a food preservative. The relative percentages are illustrated in Fig. 5.[104]

Although the calcium chloride market has been fairly balanced, in recent years market demand for calcium chloride had shifted.[105] The boom in the oil and gas drilling market has been very strong, and has contributed positively to the calcium chloride market because liquid calcium chloride is a common raw material for drilling fluids. For comparison, in 1994, the demand for calcium chloride in oil and gas exploration was just 4%.[105] Calcium chloride has also gained recognition as a superior de-icing product, and highway mixtures with sodium chloride have been found to be less corrosive than the use of sodium chloride alone in recent years.[105] Consumption within the largest market segment, de-icing, is heavily dependent on weather conditions, however, and a sharp decline in this particular market occurred over recent years as a succession of mild winters lowered demand.[105] In contrast, North American producers saw a significant improvement in 2002. Although the season started with average demand, the blizzard that hit the Northeast late in the year tightened supplies. Some producers claimed that storm caused late-

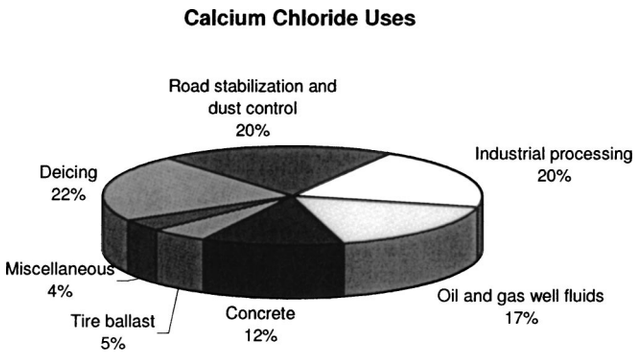

Figure 5. Chart depicting the percent use of calcium chloride among various industries.[104]

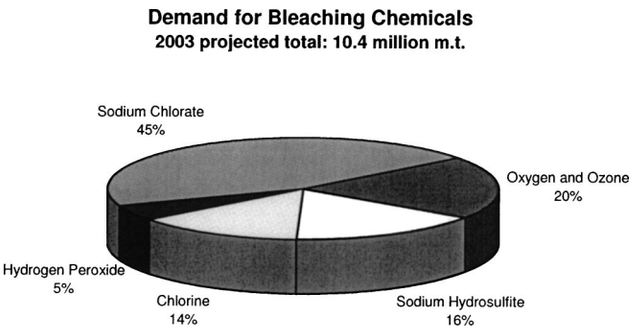

Figure 6. Demand for bleaching chemicals is projected to be 10.4 million mt in 2003 and continue to rise to 12.3 million mt in 2008, with sodium chlorate expected to increase to 51%. Source: The Freedonia Group (Cleveland).[109]

season inventory draw-down.[106] Dry summers and a continued high level of construction activity have also resulted in a steady demand for liquids for dust control.[105]

In June and September 2001, the industry had implemented price increases, and supply/demand fundamentals led to more increases at the beginning of 2002.[105] At that stage, pricing for calcium chloride ran approximately $250-260 per mt, flake; $345-$350 per metric ton, pellets; and $120 per metric ton, liquor.[105] In September, Tetra Technologies announced a price increase for liquid calcium chloride of $25 per st, effective October 1 for all noncontract customers;[107] they cited higher cost of raw material and other costs as the reason for the price increase.

Top producers of calcium chloride include Dow Chemical, General Chemicals, and Tetra Technologies, according to SRI International (Menlo Park, CA).[105] In addition to these companies there are also about ten other smaller producers.[105] Tetra completed capacity expansions at two of its calcium chloride plants, in Parkersburg, WV and Amboy, CA, earlier than anticipated; the plants were expanded by 10-20%, according to Jim Funke, VP of sales, marketing, and business development at Tetra.[105] On the other hand[108] General Chemical announced in December that it would concentrate its calcium chloride production at its 450,000 tpy plant in Amherstburg, OH and permanently close its 250,000 tpy plant in Mainstee, MI, following a period of capacity underutilization at both plants. The Amherstburg plant will operate at full capacity and meet anticipated demand for liquid and flake calcium chloride. General Chemicals also owns a 60% share in the Tangshan Sanyou (Alkali) Group that is to start up a 100,000 tpy calcium chloride plant in Tangshan, China in 2003.[108]

Sodium Chlorate

Sodium chlorate is produced by electrolysis of a brine solution followed by crystallization. Over 95% of the sodium chlorate produced today is used in the pulp and paper industry where it is a primary raw material for the production of chlorine dioxide. Over the last year or so several pulp mills have closed, and mill conversions to elemental chlorine-free bleaching (ECF) have affected the demand for chlorate.[109] Demand growth for sodium chlorate fell back after the April 2001 deadline for conversion; before that, however, there had been a surge in demand that allowed the U.S. producers to maintain operating rates at more than 90%.[110] Sodium chlorate demand was expected to be on the rise again by the second quarter,[110] and was expected to track the growth of the pulp and paper industry.[109] Pricing had been stable since July 2001, when FinnChem (U.S.) and other producers had implemented a $25/t price hike.[111] At the beginning of 2002, contract pricing for sodium chlorate was in the range of $390-$450 per ton and contract liquid sodium chlorate was slightly higher at $400-$460/t. Spot chlorate ranged from $390 to 450/t.[111] At this stage, supply and demand were just about even.[111] By August pulp mill capacity, which had been curtailed during the first quarter, had come back, and excess inventories were steadily being depleted.[112] Sources claimed that the industry was ready to absorb roughly 100,000 tons in annual capacity that had come on stream in the sodium chlorate market this year.[112] At this time contract pricing slipped to $360-440 per ton.[113] In November, Eka Chemicals increased the price of Sodium Chlorate by $25/t in the U.S. and C$40/mt in Canada.[114] Sterling Pulp Chemicals Ltd. followed suit by increasing its prices by $15/st and by C$25/mt in Canada.[115] The projected demand for 2003 for bleaching chemicals, including sodium chlorate, is illustrated in Fig. 6.[109]

Plant news.—On the supply side of the market, there were several substantial capacity shifts in 2002.[112] One large increase in capacity was Albchem Industries Ltd.'s new 40,000 tpy plant near Hargrove, Manitoba, Canada. The facility became operational during the first quarter and was built to meet growing customer demand, a spokesperson for Albchem said.[116] The Hargrove site is located near a large salt deposit and draws its electricity from Manitoba s rich hydro-energy base.[116] Nexen Chemicals is scheduled to bring on stream 70,000 mt/yr of sodium chlorate capacity at its Brandon, MB plant by the end of 2002 and complete a 69% expansion of its sodium chlorate capacity at Barrio do Riocho, Brazil, to 60,000 mt/yr by 2003.[117] The company has idled 50,000 mt/yr at its 115,000 metric tons per year plant in Taft, LA. The idled line, which uses older technology, will remain on standby as potential swing capacity. With the change in capacity Nexen will have 425,000 metric tons per year in North America.[117] Sterling Chemical announced in November that it was on target to start up a 5,000 metric tons per year (100% basis) sodium chlorate plant at Thunder Bay, ON in the first quarter of 2003.[118] The company said it would move ahead with a second 5,000 metric tons per year expansion at the site when demand necessitated it.[118] On the other hand it also announced that it would be delaying its construction of a 60,000 metric tons per year plant in Hunter Valley, Australia because of difficulty in securing funding for the project. The plant was due to start up in early 2003.[115] Its parent company, Sterling Chemicals, is in the process of selling its sodium chlorate business as part of its proposed restructuring plan under Chapter 11,[119] having filed for bankruptcy protection in July 2001.[119]

Soda Ash

Soda ash, or sodium carbonate, is an alkaline chemical refined from the mineral Trona or made from sodium carbonate bearing brines, which occur naturally. It is also manufactured through several chemical processes. European and most Asian soda ash is produced by electrolysis of limestone and brine. About 68% of the world's production is based on the Solvay synthetic process, which produces synthetic soda ash from salt, ammonia, carbon dioxide, and limestone.[120]

U.S. industry.—At the beginning of 2002 it appeared that a strengthening global economy would boost soda ash demand. Ac-

cording to CMAI (London), growth is expected to gain further momentum in 2003 and average 2.5% per year over the next 5 years.[120] According to the Chemical Market Reporter, total capacity in the United States is 15.65 million tons,[125] with American Soda accounting for 0.9 million tons, FMC 4.85 million tons, General Chemicals 2.5 M tons, OCI Wyoming 3.1 M tons, and Solvay Minerals 2.8 million tons.[128] The United States was particularly hard hit in 2001 because of a huge slug of new capacity, as well as high energy costs. As a result, approximately 18% of Northern American capacity was idled or shut down.[120] These closures tightened supply, however, and allowed producers to push through most of a $15 per ton increase on contracts, which are renewed annually in the soda ash industry. In late August, OCI Chemical Corp led a $7 per st price increase.[121] Other major players, FMC Corp, IMC Global Inc., and Solvay followed suit shortly afterward.[121] This was apparently warranted by low margins. Williams announced in March that it was planning to initiate a reserve-price auction for American Soda LLP. Reputedly, several soda ash companies looked at the assets but no bids were placed. Since the plant began operations in November 2000 it has experienced difficulties. The production facilities were built to produce roughly one million tons of soda ash and 150,000 tons of sodium bicarbonate per year. However, in the summer of 2001 American Soda set revised production goals of 500,000 to 600,000 tons for soda ash production.[122]

Another important piece of news was that IMC Chemical Inc. announced at the beginning of the year that it would be withdrawing from the American Natural Soda Ash Corp (ANSAC) after January 1, 2004 (ANSAC has a two-year exit clause) and would be exporting its own product.[123] It plans to capitalize on its proximity to West Coast ports. ANSAC takes consignment of the product at the California, Wyoming, and Colorado plant sites and ships it. It exports more than $500 million of soda ash annually to various global markets.[126] The Indian courts have upheld a petition from ANSAC that a ban on U.S. exports of soda ash to India was unfair.[124] The original petition was lodged on behalf of Indian soda ash producers in 1996.[127]

In the U.S., soda ash usage by sector is as follows: glass 50%, chemicals 27%, soap and detergents 11%, flue gas desulfurization 2%, pulp and paper 2%, and water treatment 1%.[125] Because soda ash is used in flat glass for automobile manufacture and building construction, which are important economic sectors of the domestic economy, monthly soda ash production data is incorporated into monthly economic indicators for industrial production by the Federal Reserve Board, which monitors the condition of the U.S. economy.[126] As far as detergents go, soda ash is a component of sodium tripolyphosphate ($Na_5P_3O_{10}$,STPP), a major builder in detergent formulations. Soda ash consumption has been decreasing because phosphatic detergents can contribute to eutrophication, which is an environmental concern. Moreover, new technology incorporating enzymes in dishwashing detergents and a move toward liquid cleaners may adversely affect STPP consumption in the future. Liquid detergents not containing soda ash competed with powdered detergents, and commanded around 50% of household laundry detergents by late 2001; this percentage is set to increase.[126]

World industry.—The largest consumers of soda ash are, for the most part, developed nations; end use patterns are generally the same as for the U.S.—glass, chemicals, and detergents. Outside the United States, eight countries have the capacity to produce more than 1 million metric tons per year. In descending order, these are: China, Russia, India, Germany, France, Italy, Poland, and the United Kingdom.[127] Figure 7 shows worldwide capacity by geographic region.[120] Acquisitions and/or joint ventures between major European soda ash producers may bring production facilities in the Ukraine, Bulgaria, and Romania up to similar capacity in the near future.[127] Many of the soda ash-producing countries have large populations that require consumer products made with soda ash. However, soda ash consumption in the production of glass containers is expected to decline as plastic containers and lightweight

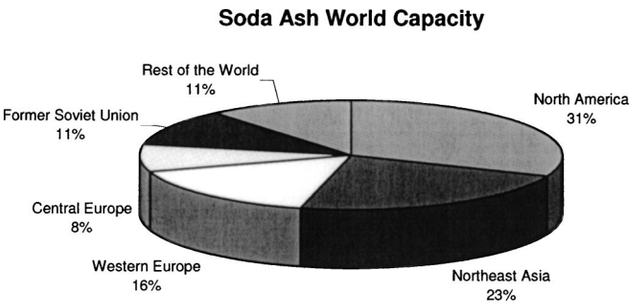

Figure 7. Worldwide capacity for soda ash. 2001 sales were $43.4 million mt. North America holds the greatest capacity. Source: CMAI (London).[120]

bottles displace glass and consequently the raw materials for glass manufacture.[128] On the other hand, glass production other than container glass should grow at 3% per year[128] as worldwide economy improves.

Nirma Ltd., a leading soda ash producer in India, announced in 2001 that it would be increasing capacity at its plant in Bhavnagar, Gujarat Province to 650,000 tpy from 420,000 tpy. The $23 million expansion was scheduled for completion by December 2002. Nirma, also a major detergent manufacturer, intends to use the additional soda ash to meet growing demand for the Indian detergents market.[126] Shiraz Petrochemical Co. of Iran announced plans to construct a synthetic soda ash plant in Shiraz; the facility, scheduled to come online in 2004, has a planned capacity of 80,000 tpy.[129] Brunner Mond (Norwich, UK) may acquire soda ash operations from Rhodia and Lars Christensen (Copenhagen)[130] in France and Germany, respectively.

The outlook for soda ash for the next five years is favorable. At the beginning of the millenium three dominant groups forged their way into becoming world leaders; Solvay S.A. of Brussels, ANSAC of the United States, and China. Asia and South America remain the likeliest areas for increased soda ash consumption in the near future. Additional shutdowns of small, uneconomic plants and industry consolidation around the world would reduce soda ash capacity and bring soda in line with higher capacity utilization rates. Should this occur, soda ash prices could stabilize, which would consequently improve the operating economics of most producers.[126]

Environmental

Although in environmental terms 2002 had its highlights, the year also had its fair share of environmental concerns. The year got off to a bad start with the derailment of a Canadian Pacific Railway (CP) train[131] near Minor, ND while en route from Edmonton, AB to St. Paul, MN. A plume of gas from the anhydrous ammonia on board was sent into the air, killing one resident, sources said.[131]

January also saw EuroChlor adopt an environmental improvement program[131] requiring the inclusion of environmental, social, and economic considerations in all business decisions. These include energy efficiency optimization, minimization of water use through increased recycling, continuous reductions of emissions to water, land, and air, optimal use of hydrogen generated in chlor-alkali production as a raw material or fuel, and safe chlorine transportation. Director Barrie Gilliatt was reported as saying that the proposals are in addition to its commitments under Responsible Care.[131] Throughout the rest of the year, a EuroChlor task force, representing a cross section of the membership, tackled the task of turning these voluntary commitments into measurable goals or sustainability indicators. It formulated 14 benchmarks distributed under three headings: Environmental Protection, Safety and Social progress, and Economic Development.[68]

In late January it was reported that Atofina Chemicals would pay $7.2 million[132] to settle EPA charges of environmental violations at its facilities in Alabama, Kentucky, and Texas. $1.9 million is to be

paid as a fine and $5.3 million are to be spent on improving pollution conditions.[132]

In late January it was reported that the European Parliament had voted on the White Paper[133] on chemicals policy late in 2001; many of the contentious calls for increased regulation and testing of chemicals were removed. The industry had argued that this would prove so time-consuming and expensive that it would render the manufacture of many chemicals almost impossible.[133]

Radian International of Austin, TX faced fines of over $4 million after a clean-up of hazardous waste at Dow Chemical s wastewater treatment plant in Midland, MI.[134] It was alleged that a defect in their system discharged black powdery waste into the air and caused leaking into the ground and roads in 1997. The wastes, tested by the Michigan Department of Environmental Quality, were found to contain dioxin.[134]

EPA proposed a consent decree under which 15 companies will pay a total of $14.1 million to clean up a former waste disposal site at Whitehouse, FL.[135] The companies, including BP, ExxonMobil, Chevron U.S.A, Chevron Environmental Management, and CSX Transportation would also pay a total of $77,000 for damages to natural resources.[135] The waste disposal pits leaked in the mid-70s, contaminating groundwater.

Along similar lines, a directive on environmental liability based on the polluter-pays principle was adopted by the EC.[136] The legislation will cover land contamination, damage to biodiversity, and water pollution.[136] Local authorities would be responsible for ensuring that operators prevent or rectify environmental damage. Public interest groups would be allowed to pressure authorities to act and, when necessary, mount legal challenges to their decisions, under the scheme.[136] However, unlike the EPA s Superfund, it would not be retroactive.[136] Approval from the European Parliament and the EU member states is still required, however, before the directive can become law in about three years time.[137]

In Europe, the Council of Ministers approved the EC s proposed ratification of the Kyoto Protocol[138] on climate change; the EU's overall commitment under the Kyoto Protocol is to reduce emissions by 8% (from 1990 levels) by 2012; the exact tonnage of emission cuts will not be fixed until 2006, however.[138] Once the Protocol comes into force any EU country that does not comply can be sued in the European Court of Justice. By March Portugal, Denmark, France, and Luxembourg had ratified their respective targets; others were expected to follow suit by June 1.[138] Environmental groups say that the EU should put more pressure on other industrialized countries to ratify the Kyoto Protocol. Tony Juniper, vice chair at Friends of the Earth International (London) said that they must keep up pressure on Japan, Russia, and Eastern Europe to make sure it becomes an international law, and step up the criticism of the U.S. and Australia.[138] The U.S., which accounts for about one-third of global emissions, withdrew its support for the Kyoto Agreement last year, and recently announced[139] its own voluntary incentive-based plan to tackle climate change. Australia says it is likely to support the U.S. proposal.[139]

The mercury problem, which was big in 2001, continued to garner attention this year. EPA said[140] that it supported further cuts in mercury emissions and proposed a rule that would tighten standards on mercury emissions from chlor-alkali plants starting in 2005. The Senate later approved a bill sponsored by Senator Susan Collins (R., ME) that would set up federal regulations to control the sale and disposal of by-product mercury from chlor-alkali plants.[141] The bill was supported by environmental and industrial groups. It would create a task force of EPA and other federal and state officials to recommend ways to manage mercury supplies from industrial and government-owned sources.[141] The legislation stems from environmental concerns about mercury stored at the Orrington, ME facility of HoltraChem, which went out of business in 2000. The mercury was sold to distributors, one of whom caused an outrage by attempting to sell it to thermometer makers in India.[142] HoltraChem is currently being sued by local environmental groups seeking clean up of mercury contamination in the Penobscot River, near the Orrington site.[141] About 3,000 tons of surplus mercury are expected to become available over the next several decades as alternative technologies replace mercury-based technology, says Robert Smerko, president at the Chlorine Institute (Washington).[141]

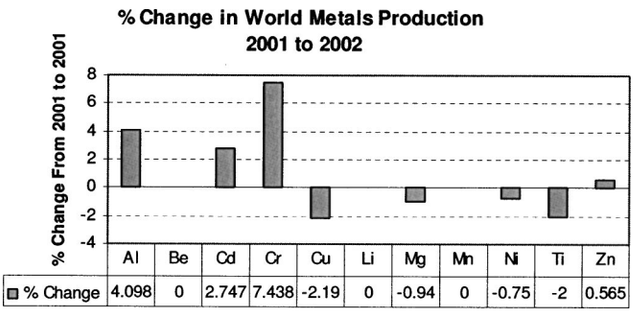

Figure 8. Percent change in world metal production from 2001 to 2002. Significant changes were seen for aluminum, cadmium, chromium, copper, and titanium, with little or no change in the rest.

A $10 million dredging operation was started in mid-October along the banks of the Hylebos waterway in Tacoma, WA[143] to remove some of the most dangerous chemicals in Commencement Bay. The chemicals were manufactured between 1947 and 1973 at a plant that once belonged to Occidental Chemical Corp. and is now owned by Pioneer Chlor-Alkali.[143] Due to its severe contamination, the sediment had to be treated before disposal,[143] so a sophisticated treatment plant stripped the chemicals from the water and mud using a combination of heat, air bubbles, and carbon filters, said Maury Wassmann, speaking for Occidental Chemical Corp. The operation called for the removal of 32,000 cubic yards of sediment, enough to fill 3,200 dump trucks.[143]

The Department of Energy's Secretary, Spencer Abraham, announced the Administration's support of fuel cell development for automobiles in January 2002.[144] This event is described further in the Fuel Cells section of this report.

Metals

While 2001 saw a significant decrease in world production of metals,[145] 2002 appeared to be better with increase in production in aluminum, cadmium, and chromium as shown in Fig. 8. Small decreases were seen between the two years for copper, magnesium, and titanium with little change in the rest of the metals. However, the U.S. market continued to struggle with only modest increases in the aluminum (2%) and cadmium (3%) with significant decrease in production for copper (16%), nickel (6%), and zinc (12%). Trends for the various metals and important news items are listed below.

Aluminum.—Aluminum stands second only to iron as the most used metal in the world. Its malleability, ductility, durability, and corrosion resistance make it popular in areas as wide ranging as transportation, packaging, construction, consumer durables, and electrical transmission lines.[146] Bauxite is the main source of aluminum and bauxite resources in the world are expected to last well into the 21st century. The U.S. does not have enough bauxite resources to meet its domestic aluminum needs and hence imports are an essential component to bridging this gap. Russia, China, Canada, and the U.S. have the highest production capacities and lead the list as largest producers in 2002. In the U.S., transportation accounted for 34% of the aluminum used, followed by packaging (25%), buildings (17%), and the consumer durables and the electrical sector (7% each).[147]

In 2002 U.S. production increased to 2,700,00 mt from 2,637,000 mt in 2001. Imports also increased from 3,740,00 mt to 4,000,000 mt This was a change from previous years, where a decline in imports was seen. Canada accounted for 60% of the imported aluminum, Russia accounted for 18%, Venezuela 4%, and Mexico 2%. Aluminum recycling has become an important source

of fresh metal in the U.S. with as much as 3 million tons coming from scrap. This represents 20% of apparent consumption.[147] On the world market, total aluminum production increased,[148] both due to new plants and restarting of idled plants. Inventories for the metal at the London Metal Exchange (LME) were at levels not seen since 1995.[147] The world markets were estimated to see a surplus of 480,000 to 643,000 mt by the end of 2002. This trend is expected to continue into 2003.[149]

North American market news.—Almost the entire Pacific Northwest aluminum output, close to 1.6 million mt, had been shut in 2001 due to rising power costs. Weak prices in 2002 resulted in these plants remaining shut. Despite these conditions, Alcoa restarted a 270,000 mt/yr smelter and Columbia Falls has started work to get back its 168,000 mt/yr smelter online. However, the closures in many of the plants in the Pacific Northwest are expected to continue because many high cost plants are located in this region.[150] The problems due to high electricity costs resulted in Golden Northwest Aluminum's plans of restarting its smelter being endangered. The company was unable to reach an agreement for the purchase of power at lower costs from utilities. The company said that it has been unable to find a way of opening two of its smelters, one in Washington and another in Oregon.[151] Subsequently, Golden entered into an agreement with Hydro Aluminum Metal Products North America to convert Hydro's raw material into aluminum for a fee based on the price of aluminum. This allowed Golden to restart its Goldendale Aluminum plant in Washington using power purchased from the market.[152] The company said that the agreement would allow it to vary production to reflect power price changes.[153]

Wabash Alloys has acquired the Culp Aluminum Alloy plant in Steele, AL. The plant, which recycles scrap, has an annual production capacity of 120 million lb. In addition, growth in the automotive sector in the area has prompted Wabash to restart its idled Russellville, Al, plant.[154] The company also shut down one of the three furnaces in its Benton, AR, recycling facility following a workforce reduction.[155]

Kaiser Aluminum Corp. has declared bankruptcy. The company voluntarily started Chapter 11 proceedings on Feb 11, 2002. The company reported assets of $3.3 billion and debts of $3.1 billion in Dec 31 2001. Kaiser has filed a list of 50 companies to whom payment is due.[156] Kaiser later announced that they would be selling their 73,000 mt/yr smelter in Tacoma, Washington, to the Port of Tacoma because the smelter was unable to compete with other, more-efficient smelters both in the U.S. and overseas.[157]

The Coris Group has decided to move away from the aluminum market and concentrate on its core carbon-steel business. The company sold its 20% stake in Aluminerie Aloutte smelter in Quebec to Alcan.[158] The company still has two smelters, one in the Netherlands and the other in Germany, as well as extrusion and rolling mills in Germany, Belgium, Canada, China, and the Netherlands. The company is in talks to sell all these assets.[151]

World market news.—Chinese aluminum consumption in the first part of 2002 was balanced by supply. However, expectations are that as much as 10% growth will be seen in the industry for both 2002 and 2003.[159] This was reflected by a number of expansions and new plant construction announced this year. The Xiezhou Aluminum plant in Shanxi province announced a planned expansion of capacity to between 330,000 and 350,000 mt/yr from the present 200,000 mt/yr. The expansion is expected to start late 2002. The Yimei Group has started construction of a 100,000 mt/yr refinery which the company hopes will open by late 2003.[160] Longlin Aluminum, based in China, plans on starting a new 100,000 mt/yr ingot smelter. Construction is expected to start soon and the project completed in 15-18 months.[168] Quaotou Aluminum plans to complete construction of its new 150,000 mt/yr plant by the end of 2003. The project was started in March and one phase is expected to be online by December 2002 or early 2003.[161] Shanxi Guanlu Co announced that it has started construction of a smelter which is expected to be completed in late 2003. The expected capacity is 200,000 mt/yr.[162] Lanzhou Aluminum and Aluminum Pechiney, based in France, have agreed to team up to start a smelter in Gansu province, China. The smelter, project to be 260,000 mt/yr, is expected to be started in 2003.[163]

Alcan has signed an agreement with Qingtongxia to take a 50% stake in the smelter in China's Ninxia autonomous region. Under the agreement Alcan also has the option for a 50% stake in the planned expansion at the site.[163] Aluminum Corp. of China (Chalco) and Alcoa have a 50/50 joint venture at an alumina plant at Pingguo, China where capacity was expanded to 850,000 mt/yr. Both companies plan on formalizing the agreement in the second half of 2003 and further increase capacity by 250,000 mt/yr.[164]

The Indian government's attempts to privatize the aluminum industry were met with protests, and a strike was declared by the workers and officers of state-run National Aluminum Co (Nalco). The strike was announced after the deadline for bids expired. India's Hindalco Industries and Sterlite Industries as well as U.S.-based Alcoa, French-based Pechiney, Alcan (Canada) and Gelncore (Swiss) are some of the companies that have submitted bids.[165] The Indian government plans on selling 10% of Nalco to the domestic and 20% to overseas markets.[166] Nalco is also planning on forming a joint venture with Pechiney, based in France, to build a aluminum complex, with a mine and a smelter in eastern India.[167]

Weak growth in domestic consumption, combined with poor exports, has resulted in little growth in Russian aluminum, contrary to previous estimates. It is expected that 2003 will also see little growth in this market.[168] Russian Aluminum (RusAl) purchased 30% stake in Ukraine's largest alumina smelter, Mykolayiv Alumina Plant. Part of the agreement involved RusAl building a new smelter in Ukraine. The company announced in November that the project will start as per schedule and expects completion in 2005.[169,170]

Alcoa has reached an agreement with the Government of Iceland and the power company Landsvirkjun to build a 295,000 mt/yr smelter in eastern Iceland. The project is expected to be completed in early 2007.[171]

BHP Billiton is expanding capacity at its aluminum complex in Mozambique involving building a new 253,000 mt/yr smelter alongside the existing one. Construction was 60% complete at the end of September and the plant is expected to be operating at full capacity by the end of 2003.[172]

Beryllium.—Beryllium, with its high strength, light weight, and stability over a wide temperature range, is used principally in aerospace and defense applications with these sectors accounting for as much as 80% of consumption. In addition, beryllium-copper alloys have good electrical and thermal conductivity and hence find use in a wide variety of applications, especially in the telecommunication and computer sectors. The U.S. is one of the largest exporters of processed beryllium ores and supplies the metal to the rest of the world.[173] The metal is produced from either the bertrandite ore (mined mainly in the United states) or from beryl (mined in the former Soviet Union and Brazil).

Brush Wellman accounts for a large fraction of the ore mined in the world, mainly from their mines in Delta, UT.[174] The company also ships beryllium hydroxide to its plant in Elmore, OH, where it converts this compound to alloys, metal, and oxide. NGK Metals Corp., based in Reading, PA, also purchases beryllium hydroxide from Brush Wellman to produce alloy compounds at its Sweetwater, TN plant.[175]

Mining has been declining in recent years with imports becoming increasing popular. While 243 mt of beryllium was mined in 1998, this decreased to 100 mt in 2002. Correspondingly, imports increased from 50 mt in 1998 to 120 mt in 2002. 30% of the imports were from Kazakhastan, 16% from Russia, 9% from Brazil, and 8% from the Philippines. However, the net mining of the metal decreased in 2002 compared to 2001. Nevertheless, the total amount of exported metal increased from 60 mt in 2001 to 100 mt in 2002. Beryllium-copper alloys were also recycled, although not much data was available.[176]

With the downturn in the economy being especially hard on the technology sector, demand for beryllium from the telecommunication and computer industries decreased compared to 2001. Around 50% of Brush Engineering Materials sales are in this sector and the company announced that it had significant excess capacities and inventories during the first half of 2002. The company embarked on cost cutting measures, including a 22% manpower reduction.[177] However, sales to the defense sector increased. Exports of finished products also increased with Canada, Germany, Japan, the Republic of Korea, and the Netherlands being the major importers.[176] The U.S. government also stockpiles beryllium to ensure supply in an emergency. The stockpile goal for the Defense National Stockpile Center in Dec 2001 was 45 mt In 2002 the center sold 18 tons of the metal and proposes to dispose 36 tons in 2003.[176]

Cadmium.—Cadmium is produced mainly as a byproduct of mining, smelting, and refining sulfide ores of zinc, lead, and copper. In addition, dust from the recycling of iron and steel scrap also produces this metal. Three-fourths of the cadmium produced is used in batteries and the remaining for pigments, coatings, and in plating baths.[178] World consumption of cadmium decreased in 2002 compared to 2001. 13,134 mt were consumed in the first 8 months of 2002 compared to 13,760 mt during the corresponding period in 2001. While production also fell, the rate of fall was greater than the rate of decrease in consumption, thereby resulting in a deficit of the metal.[179] The environmental implications of using cadmium and the shift to metal hydrides and lithium-based cells are expected to impact this sector in the years to come.

Only two companies produce cadmium in the United States. Pasminco Ltd, based in TN, produces the metal as a byproduct of smelting and refining zinc concentrates and The International Metals Reclamation Company Inc., based in PA, produces secondary cadmium mainly from spent Ni-Cd batteries.[180] The market was weak in 2002 with production staying flat at 700 mt (compared to 680 in 2001 and 1240 in 1998). Imports decreased significantly from 107 mt in 2001 to 10 mt in 2002 with Canada accounting for 39%, Australia 29%, and Belgium 23% of the total metals imported. However export of the metal remained steady at 300 mt (up from 272 mt in 2001).[181]

The Big River Zinc Corporation, owned by Korea Zinc Co., closed operations in the end of 2000. The company, even after upgrading its facilities in mid-2002, decided not to resume production of cadmium due to low prices and loss of market from Ni-Cd batteries. The environmental issues associated with cadmium have resulted in regulatory pressure to reduce or eliminate the use of this metal around the world. The U.S. EPA has identified 11 metals that are named as persistent and bi-accumulative toxic pollutants, with cadmium being one of them. The usage of the metal is slated for 50% reduction by 2005. In addition, the European Union (EU) is evaluating a ban on all Ni-Cd batteries containing more than 0.002% Cd from Jan 1, 2008.[181] The EU also proposes the ban of Cd in new electronic equipment beginning Jan 2006.[182] This metal is also being substituted wherever possible. While Ni-MH and Li-ion batteries are becoming increasingly popular, Zn and vapor-deposited aluminum are being substituted for cadmium in plating applications.[181] These trends suggest that the market for this metal will continue to be weak in coming years. However, less stringent environmental laws in China have resulted in strong demand for cadmium, with batteries for power tools being the main end use. Chinese use of cadmium was estimated to be 6,500 mt/yr and merchants suggest that this is the only market for the metal in the world.[179]

Chromium.—Chromium enhances the hardness and resistance to corrosion and oxidation of iron, steel, and other nonferrous alloys. Main uses are in the production of stainless steel, alloys, plating baths, pigments, and in the leather industry.[183] World reserves exceed 12 billion tons of chromite ore, which is expected to meet demand for centuries. 95% of the reserves are located in southern Africa with some reserves in Kazakhstan. These two countries, along with India, accounted for 76% of the world production in 2002.[184]

Production in the United States in 2002 was 153,000 mt, up from 122,000 mt in 2001 and 104,000 mt in 1998 with the country accounting for 14% of the world consumption. Imports of the metal decreased significantly from 385,000 mt in 1998 to 239,000 mt in 2001 down to 174,000 mt in 2002. The U.S. imports 50% of the metal from South Africa, followed by 20% from Kazakhstan, 9% from Zimbabwe, 7% from Turkey, and 6% from Russia. Recycling of the metal from stainless steel scrap accounted for 37% of the consumption and the government stockpile released 87,000 mt in 2002, compared to 9,000 mt in 2001.[184]

Chromium has no substitute in the making of stainless steel (the largest end user), superalloys, and in chromium chemicals. Hence demand for this material can be expected to be strong.

Copper.—Owing to its ductility, malleability, thermal and electrical conductivity, and resistance to corrosion, copper is an important industrial metal. 75% of copper usage is in the power transmission, wiring and telecommunication, and electronic component sectors.[185] Building construction accounts for 44% of the market, followed by electrical and electronic products (25%), transportation equipment (11%) and industrial machinery (10%). World resources for land-based copper are estimated to be 1.6 billion tons and nodules in the sea are estimated to have another 700 million tons. Chile has the world's largest reserves and the largest mined copper at present.[186] In the U.S., mining of copper decreased from 1,340,000 mt in 2001 to 1,130,000 mt in 2002. Copper recycling from scrap is also an important business accounting for as much as 9% of the consumption.[186] The U.S. has remained the largest consumer of copper for decades. However, it is expected that in coming years China will overtake the U.S. due to economic growth in the region.[187] Global copper demand rose 1.6% during the first 9 months of 2002 compared to 2001, mainly due to Asian consumption with 19.9% rise in China and 8.9% in South Korea.[188]

2002 saw a dramatic cutback in copper production after 7 years of strong growth with producers in the U.S. and Chile instituting cutbacks. While the 19% growth in Chinese consumption helped the market in the first half of the year, world use rose only 1%. Inventories, which rose in 2001, continued to rise until midyear when reversals were seen. Prices, which rose in the beginning of the year, fell back to December 2001 levels by September[186] with weak orders.[189] The U.S. market was steady with little growth by the end of the year. However reports suggest that 2003 would see a deficit.[190]

North and South American market news.—BHP Billiton has decided to permanently close the copper mine at Manuel, AZ. The mine had been idled since 1999 due to high costs and low copper prices. The company is in negotiations to see if the smelter at the site can be sold.[191] Billiton also announced that it will be extending cuts at the Escondida and Tintaya mines until the end of 2002.[192-194] However, by the end of the year, the company announced that the cut would extend into 2003.[195]

Canada based Noranda announced that it plans to permanently close its 135,000 mt/yr smelter at Murdochville, Quebec. The company says that the smelter is not economically viable. Noranda had previously decided to suspend operations because of weak market conditions.[196] Labor strikes also cut production at Noranda's 220,000 mt/yr Horne smelter in Quebec in June to below 50%.[197]

Codelco announced that it plans on reducing production because of weak market conditions at the Chuquicamata division in Chile. However, the company also seems to be persuing acquisitions and expansions in other plants. Codelco was bidding for ExxonMobile's Disputada Mining Company, which has the same ore body as Codelco's Andina mine. CEO Juan Herrera expects electric car production to be a big growth area for the company in future.[198] Codelco also plans to expand capacity at its Caletones smelter from 380,000 mt/yr to 435,000 mt/yr.[199] Antofagasta Minerals plans on reducing production at its Los Pelambres mine in Chile from 374,000 mt/yr to 330,000 mt/yr. The company will be mining a section that has a lower content and are keeping their long-term

plans in order. A planned expansion at its milling plant at the site has been delayed because of environmental issues.[198] In early June a mudslide resulted in a four day closure of the plant, although the company said that it was still on schedule to produce the target amounts for the year.[192] A joint venture between Codelco and BHP Billiton, Alliance Copper Ltd., has begun construction of a bioleaching copper plant in the Chuquicamata complex. The company predicts that it would reach capacity by end 2003.[200]

The La Caridad mine, operated by Grupo Mexico, which had halted copper output because of a strike, reopened in April, although the company kept its smelter and refinery running during the strike. The impact of the strike is thought to be minimal.[201] The union workers at the Southern Peru Copper Corp., partly owned by the Grupo Mexico's subsidiary, Asarco, announced that they would go on strike late October to dispute workday schedules.[202,203]

Asarco is planning on selling its stake in Southern Peru Copper to its parent, Grupo. However, the move is opposed by the U.S. Justice Department, which cites extensive environmental liabilities. Asarco had earlier informed the government that it would be unable to meet the costs of cleanup because of low copper prices. The company also has a number of civil liabilities in different states in the U.S.[204] Asarco also announced that it was going to further reduce production at the Mission mining complex in Arizona. The company said that this would also lead to reductions at its smelter at Hayden, AZ. The move was to save money for the cash strapped company.[205]

The world's largest iron-ore producer, Cia Vale do Rio Doce, based in Brazil, plans on entering the copper market by 2008 with construction of a $400 million, 140,000 mt/yr copper project in Sossego. The company also has plans of opening four other mines in the eastern Amazon.[201] In addition, Cia Vale has signed a contract to buy out Anglo American's stake in the Salobo Metais S/A copper project.[206]

European market news.—MK gold said that it expects to get mining concessions at its Las Cruces copper project in Spain by the end of June. Once the government gives final approval, the company plans on construction in mid 2003.[200] Murchison United, based in Australia, announced that it was close to buying Rio Tinto's 49% stake in the 100,000 mt/yr Neves Corvo Copper mine in Portugal. This occurred as Outokumpu announced that it is withdrawing from an earlier deal to buy 8% stake in Neves Corvo.[200] Production at Umicore's Pirdop smelter in Bulgaria had been halted in April to carry out expansion. The company expects capacity to go up from 210,000 mt/yr of anode and 45,000 mt/yr for cathode from 146,000 mt/yr and 34,389 mt/yr.[200]

The liquidators of RBG resources, based in the U.K., are in talks to sell the company's copper operations in Romania to pay debts. However, the asking price is thought to be too high for the amount of metal produced.[207] Russian metals giant, Norilsk, announced that it would boost copper sales to domestic markets and cut exports. The company's copper output rose 14% in 2001 and is expected to also increase in 2002.[208] Mansfelder Kupfer and Messing is thought to be closing its copper refinery at Hettsteadt in central Germany. Shortage of copper scrap due to decreasing imports from Russia is forcing the move.[209]

Asian, African, and Australian market news.—The Indian government plans on privatizing the state owned Hindustan Copper Limited and has enlisted bids. Three Indian companies, Birla Copper, Sterlite industries, and Finolex cables, are in the running along with UK-based Metdist. The government plans on selling the 98.7% stake it presently holds along with management control.[206]

Nippo Mining and Mitsui Mining, both based in Japan, are planning to merge their copper operations in April 2003. The two companies will transfer operation to a joint venture, Pan Pacific Copper, in July.[210]

Domestic scarcity in China was reported to have resulted in nine of the countries largest copper producers joining hands to form a new company-China Nonferrous Metal International Mining Co. The new company seeks to develop mines in neighboring countries including, Indonesia, Myanmar, Mongolia, and Kazakhstan.[211] However, by the end of the year this reported scarcity appeared to have been reversed with robust demand reported.[212] Outokumpu announced in September that it had completed an expansion of its copper tube plant in Zhongshan, China, with the capacity doubling to 25,000 mt/yr.[213]

Vietnam is planning on building its first cathode production plant with a capacity of 20,000 mt/yr. The government, which made the announcement, expects the plant to be completed in end 2004.[214]

Anglo American had withdrawn from the Konkola copper mining operation in Zambia, which has resulted in the government planning on taking over the mine. The government is enlisting help from the World Bank and other cooperative partners in trying to keep the mine from closing.[215]

A series of explosions rocked the Port Kembla copper smelter in Eastern Australia. The explosions occurred due to spillage of molten metal in the casting port. The state politicians have called for a plant closure until an enquiry has been held.[192] Another Australian copper producer, Mount Isa, also had to close operation due to a fire on the tapping floor. The plant was expected to be out of commission for a week.[192] The company later announced that it plans on an expansion at the plant to 400,000 mt/yr from 287,000 mt/yr within the next four years.[216]

Lithium.—The U.S. is the leading consumer of lithium minerals and the leading producer of value added lithium materials. Chile is the largest producer of lithium in the world. Argentina, China, Russia, and the U.S. also have large production facilities. Australia, Canada, and Zimbabwe are leading producers of lithium ore concentrates. Lithium usage in ceramics, glass, and aluminum production accounted for 60% of consumption. Other uses are in manufacture of lubricants, greases, synthetic rubber, and in batteries. The total identified world resources account for 760,000 tons in the U.S. and more than 13 million tons in other countries.[217]

Production data in the United States are withheld because only one company produces lithium compounds in the U.S. Imports rose in 2002 to 2500 mt compared to 1990 mt in 2001. This represents a change from the previous year, which saw a decrease. Chile accounted for 80% of the imports, followed by Argentina with 16%.[217] Lithium carbonate production is dominated by the use of subsurface brine as a raw material because of lower production costs compared with hard-rock ores. Two brine operations in Chile dominated the world market, while a facility in Argentina produced lithium chloride and lithium carbonate.[217] Little change was seen in the U.S. with only one active lithium carbonate plant remaining, which was a brine operation in Nevada.[217]

Two companies in the U.S. produced lithium compounds from lithium carbonate, both from domestic sources and imported from South Africa. A recycling company produced lithium carbonate from recycled lithium batteries. However, this represented an insignificant portion of the production at the time of reporting, although it appears to be growing. A fertilizer producer from Chile entered the market in 1997 and undercut prices by around 50% to establish market share. This resulted in higher cost facilities closing. However the markets have stayed steady, with prices increasing by 10% in the end of 1999 and again in 2000 and 2001.[217] Xinjinag, based in China, announced that it would be embarking on a project to upgrade their ingot plant and improve its quality. The company, which produced 60 mt lithium in 2001, mainly exports to Japan and India. The company produces Li mainly for the battery industry.[218]

Manganese.—Manganese has excellent alloying properties, which makes it invaluable in the iron and steel sector. As much as 85 to 90% of the United States demand for this metal is in the steel industry. Manganese is also used in aluminum alloys and in dry cell batteries. As an ore, it is used as a plant fertilizer, animal feed, and colorants for bricks.[219] South Africa and Ukraine account for more

than 80% of the world's identified resources. China, Brazil, India, Mexico, Gabon, and Australia also have mine production of this metal.[220]

In the U.S., manganese ore containing more than 35% of manganese was not produced domestically in 2002. Imports rose to 500,000 mt from 358,000 mt in 2001 for manganese ore, while those for ferromanganese and silicomanganese decreased. While ferromanganese decreased from 249,000 mt in 2001 to 220,000 mt in 2002, silicomanganese decreased from 269,000 mt to 200,000 mt Plants in the eastern and Midwest U.S. were the main consumers of the ore. Gabon accounted for 70% of the ore imported, followed by South Africa (10%), Australia (9%), and Mexico (5%). South Africa accounted for 47% of the ferromanganese imported, followed by France accounting for 22%, with Mexico and Australia accounting for 8% each.[220]

Steel production, which is a major end user for manganese, stayed at the same level as in 2000 and 2001 globally, although the industry was down in the U.S. However, shortages in supply of ferromanganese resulted in prices tending upwards at the end of 2001. Manganese ore, on the other hand, saw decrease in prices, because of a decrease in the international benchmark price set between Japan and major suppliers in June 2002.[220]

Companhia Vale do Rio Doce S.A., a manganese ferroalloy producer based in Brazil, completed its acquisition of Elkem ASA's ferrochrome plant in Rana, Norway in early 2003. The plant had previously been closed. The company expects the plant to be converted to manganese ferroalloy by late 2003. The plant will be renamed Rio Doce Manganese Norway.[220]

Magnesium.—Magnesium and its compounds (mainly magnesium oxide) are predominently used as refractory materials for furnaces producing iron and steel. In addition, they find use in agriculture, chemical and construction industries.[221] The metal is found all over the world and is virtually unlimited.[222] The largest use of magnesium in the U.S. (representing 46% consumption) is in making an aluminum alloy used in packaging, transportation and other applications, followed by structural uses (32%), desulfarization of iron and steel (13%), and as a reducing agent in nonferrous metal production (2%). The U.S. production capacity stayed steady in 2002 at 45,000 mt (same as 2001), while import of the metal went up from 60,000 mt to 90,000 mt with Canada accounting for 42%, China for 20%, Russia 16%, and Israel 11%.[222] While 2001 saw shutdowns among western producers, increased output from China and 10% drop in worldwide demand appears to have resulted in a market oversupply.[223]

U.S. Magnesium purchased the assets of Magnesium corp. (Magcorp) in June and announced that it would modernize and expand capacity at its plants in Utah. The company is implementing a new generation of electrolytic cells designed to decrease chlorine emissions and reduce costs.[224]

Leader Mining International and the State Research and Design Titanium Institute (STI) of Ukraine along with VAMI of St. Petersburg, have signed a technology transfer agreement related to Cogburn magnesium project in British Columbia. VAMI/STI will provide its technology, considered the leading magnesium reduction process, for pilot scale testing on magnesium recovered from Cogburn's magnesium silicate.[225,226]

French magnesium producer Pechiney has not been producing magnesium at their Marignac plant since May 2001. In July 2002, the company announced that the plant would be closed. This closure is thought to hasten the removal of anti-dumping duties imposed on Chinese manufacturers.[227] The company plans on converting the plant into a recycling plant, although concerns remain as to the ability of the new entity to complete with existing recyclers.[228]

Wenxi Yinguang, China's largest magnesium producer announced that it will increase output by 17% in 2002 to 28,000 mt The increase reflects a new production line reaching full capacity after ramping in 2001.[218] The company also has plans for a new plant slated to open in end 2002.[229] Shanzi Qizhen also announced that it will be increasing output from 3,000 mt/yr in 2001 to 5,000 mt/yr.[230] According to a company official, this is a reflection of the increasing demand for the metal from foreign markets.[231] These seem to be part of a trend in the Chinese magnesium industry with Guangling Jinghau magnesium, in Shanzi province, and Hebi Jianghai Smelting Co., in Henan province, announcing increased capacity in 2002 and Ningxia Zhongning Aluminum announcing that it will be entering the magnesium market. Opportunities in foreign countries appear to be the cause for the spurt in the market.[232] Hydro Magnesium has opened a new plant in Xian, China with a capacity design of 6,000 mt/yr although the plant is thought to be capable of producing 10,000 mt/yr. The Hydro Magnesium Xian Co. would be producing magnesium for the Chinese market.[233]

Magnesium Alloy Corp., based in Canada, is planning on a magnesium project in the Republic of Congo at a capacity of 60,000 mt/yr. The project, although first announced in 1997, appears to be forging ahead with the company signing a power agreement with a local plant.[234]

Australia's Rumbora Technologies plans to produce 100,000 mt/yr magnesium at a plant in Victoria using fly ash. The cost of the plant is expected to be $535 million.[230] Magnesium corp. of Australia is also starting a plant in Queensland and is expected to be operational by Dec 2004. The company hopes to achieve full capacity (97,000 mt/yr) in 12-19 months after startup.[235] Pima mining, in reflection of its expected entry into the magnesium market, has changed its name to Magnesium International. The company plans on building a plant in Port Pirie, Australia.[233]

Nickel.—Nickel is mined from two types of ore deposits, namely laterites and magmatic sulfide. 65% of the nickel is consumed in the making of austenitic stainless steel and 12% in the making of superalloys and nonferrous alloys, both being widely used because of their corrosion resistance and used primarily in the aerospace industry. Another 23% is used in making alloy steels, for rechargeable batteries, catalysts, and other chemicals.[236] World resources of nickel are estimated to be approximately 130 million tons with 60% in laterites and 40% sulfides.[237] In the U.S., 32% of the metal ended in the transportation sector, 13% in the chemical industry, 10% in electrical equipment, 9% in construction, 8% as metal products, 7% in household appliances and 6% each for the petroleum and machinery industry. Stainless steel production in the U.S. went up 30% in 2002 compared to the previous year, which resulting in increasing demand for nickel.

Nickel supply grew faster than demand in late 2001, causing a buildup of stocks and by June 2002 had climbed back to above 20,000 ton in the LME. Although world production was at an all-time high in 2001, prices increased in early 2002 and peaked in mid-year.[237] The North American demand was weak for the metal, especially in the superalloy sector. Demand was also weak in Europe for part of the year.[238] However, China has seen strong demand in 2002 and is expected to offset losses leading into 2003.[239] Demand from the stainless steel industry is the cause for the increase. Current demand for nickel is estimated to be 80,000-90,000 mt/yr while the largest local supplier, Jinchuan Nonferroous produces only 40,000-50,000 mt/yr. Therefore, significant imports are expected into 2003.[241] Alan Heap of Salomon Smith Barney, Australia, told the Australian Journal of Mining's fifth annual world nickel congress in Sydney that the outlook for nickel is upbeat with markets being supported by small increases in supply, low inventories, restricted scrap metal supply and strong stainless steel production. He predicted that the market would grow by 3.3% in 2003.[240]

The government of Newfoundland and Inco Ltd. reached an agreement to develop sulfide deposits in the Voisey's Bay in Northern Labrador with mine construction commencing in mid-2002, thereby clearing a three-year impasse. Inco is also developing a laterite deposit mine at the southern tip of New Caledonia using an advanced high pressure leach technology. This technology appears to be gaining ground with sites in Cuba, Indonesia and the Philippines considering its use.[237] The site is thought to be the largest undeveloped nickel deposit.[241] Inco has reduced production at its plant in Manitoba, in Canada, because of a need to change the ore

blend. The plant produces electrolytic nickel for the plating industry.[239] The company is also rebuilding a furnace on the island of Sulawasi, in Indonesia, both of which has resulted in low stocks for the metal.[239]

Rio Narcea Gold Mines, Ltd., has successfully arranged financing for its Aguablanca mining project in southwestern Spain and is expected to produce 9,100 mt/yr of nickel. Construction is expected to cost $64 million and the life of the mine is expected to be 10.5 years.[242] LionOre Mining International Ltd. has acquired 43.35% equity position in Tati Nickel Mining Co., held by Anglo American plc, based in the UK. This increases the equity of LionOre in Tati to 85% and is reported to cost $75.9 million.[243] JGC corporation, based in Yokohama, Japan, has won a contract to construct a nickel extraction complex at the Rio Tuba Mine on Palawan Island in the Phillipines. The plant will use the high-pressure acid-leach technology and is to be opened next to the mining pit owned by Rio Tuba Nickel Mining Corp. The plant will produce a nickel-cobalt sulfide feedstock to be sold to the Sumimoto Metal Mining Co., based in Japan.[244]

Titanium.—Titanium is well known for its corrosion resistance and its high strength to weight ratio. Only three forms of the mineral in which the metal occurs (ilmenite, leucoxene and rutile) are of economic significance.[245] Ilmanite supplies 90% of the world demand for titanium. The world resources are estimated to be 1 billion tons of TiO_2. Identified world resources of rutile total 230 million tons of contained TiO_2.[246] 95% of titanium is consumed as titanium dioxide and is used in paints (49%) paper (16%), and plastics (25%).[247] In 2001, around 65% of the titanium metal used was in the aerospace industry and the remaining in armor, chemical processing, power generation, marine, medical and sporting goods.[247]

U.S. market news.—The U.S. production of TiO_2 pigment was estimated to be 1.38 million tons, up 4% compared to 2001. Imports increased by 10%, while exports increased 13% with consumption up 5%. For sponge metal, imports decreased by 5% while consumption decreased approximately 27%. Sponge metal was imported primarily from Japan and Russia (36% each) followed by Kazakhstan (25%), while TiO_2 pigment was mainly imported from Canada (33%), followed by Germany (12%), France (8%), Spain (6%) and China (5%).[247] The slowing economy resulting in a decrease in the consumption of titanium concentrates, but the U.S. saw an increase in imports by 7% with South Africa accounting for 46%, followed by Australia (32%), Canada (14%) and Ukraine (4%).[246]

E. I. duPont de Nemours and Co. has changed the name of its titanium minerals and pigment unit from DuPont White Pigments and Mineral Products to DuPont Titanium Technologies, in lieu of its business direction. Altair Nanotechnologies Inc, was granted a patent for converting titaniferous ore to TiO_2, based on the technology acquired from Broken Hill Proprietary.[248]

World market news.—Bemax Industries, based in Australia, has received approval from the New South Wales Ministry of Planning to develop its deposits in Murray Basin and is expected to be commissioned in 2003. Millenium Chemical Inc., based in France, doubled the ultrafine TiO_2 pigment capacity at its Thann facility to 10,000 tons per year. The material is used in electroceramics, photocatalysts and uv radiation blockers. QIT Madagascar Minerals SA has obtained environmental permits from the government of Madagascar for its mining projects and clears the way for market and engineering studies. Ticor SA (formerly Iscor Heavy Minerals), based in South Africa, has started shipment of concentrates from its Hillendale mine near Empangeni. The plant was recently commissioned.[248]

RTI Energy systems, a subsidiary of RTI International Metals based in Ohio, which manufactures titanium products, has been awarded a contract to produce hydrocarbon production equipment. This would be in connection with Unocal's West Seno project off the coast of Indonesia. The company will provide engineering design and manufacture components based on titanium and steel.[249]

Kobe Steel, based in Japan, and U.S. based Titanium Metals Corporation (Timet) have entered into an agreement to manufacture and sell Kobe Steel's Ti-9 alloy in North and Central America and in Europe. Under the agreement, which runs until 2019 when the patent expires, Kobe will receive royalties from Timet. While Kobe will continue marketing the alloy in Japan and east Asia, Timet will cover the U.S., Canada, Mexico, UK, Germany, Belgium, Spain, France, and Italy. The alloy, which contains 4.5% aluminum, 2% molybdenum, 1.6% vanadium, and traces of iron, silicon, and carbon, is presently used for the production for golf club heads. Both companies seek to identify new markets including the aerospace industry, spurred by Kobe's claim that the production costs are 30% less than the presently used alloy (Ti-6Al-4V), which accounts for as much 80% of the global demand, amounting to 20,000 mt/yr.[250]

Sumitomo Metals Industries, also based in Japan, has signed an agreement with Airbus, the airline manufacturer, to supply commercially pure titanium sheets. The contact, which lasts 3 years, will result in Sumitomo manufacturing the metals and delivering it to plants in Europe.[251]

Zinc.—Zinc is used in a range of products with 85% consumed as a metal and the rest used for making of rubber, chemicals, paints and in the agricultural sector. While 55% was used in galvanizing, 17% was used in zinc-base alloys and 13% in brass and bronze.[252] It is popular as a coating for iron and steel to prevent corrosion.[253] The identified world resources are 1.9 billion tons with Australia, China, Canada, Peru, the U.S., and Mexico having a large share of the market.[252]

In the U.S., mined zinc decreased in 2002 to 740,000 mt from 842,000 mt in 2001 while both primary and secondary slab zinc increased from 203,000 to 210,000 mt and 108,000 to 130,000 mt, respectively. Imports of ore and concentrates decreased from 84,000 mt in 2001 to 80,000 mt in 2002, while that for the refined product increased from 813,000 to 900,000 mt The combined imports were split among Canada (54%), Mexico (12%), and Kazakhstan (8%).[252] The price of zinc in the LME reached the lowest level in 15 years in 2002 and stocks reached the highest level since 1996. This downturn in the industry resulted in either closures or temporary suspension of operation. Both Noranda and Pasminco announced that they will resort to production cuts.[254] These closures are expected to result in consolidation of the zinc industry.[252] Zinc remained weak in the first part of the year, but the situation appeared to improve later in the year. However, excess supply hindered a strong rebound in prices.[255] However, metal for immediate delivery appeared to be in short supply.[256]

In contrast, the zinc market in China and Japan remained strong much of the year. Both countries are expected to see an increase in demand for 2003. Japanese firms have seen healthy local sales as well as exports to China and other southeast Asian countries.[257] This was in contrast to reports early in the year when the Japanese market was stalling and expectations for the year were bleak.[258] However, by April, the market was looking up, with three Japanese firms raising production targets in expectation of stronger demand.[259] Zinc production in India was also higher in 2002 with both producers, Hindustan Zinc and Binani Industries seeing a 15% increase. Binani Zinc plans on increasing its smelting capacity by 233%, but is waiting for government approval. The company has reached agreement with Korea Zinc and Umicore for collaboration in the undertaking.[260]

North and South American market news.—Noranda, based in Canada, has decided to postpone the development of its Perseverance zinc deposit near Matagami, Northern Quebec. The company said that present zinc prices do not allow it to explore this option, but remained confident that the development would occur in 2005-2006. The mine is thought to have total resources of 5.1 million mt The company presently operates another mine at Matagami, the Bell-Allard, which is expected to close late 2004. It would appear that there would be a 15 month delay between the closing of this mine and the opening of the new one, if the company's plans remain

the same.[261] Korean Zinc, which owns the Big River zinc refinery, in Illinois has announced that it will upgrade its facility at a cost of $10 million.[255]

The Peruvian subsidiary of Trafigura Beheer BV, Cormin, was expected to start work in early 2003 for expansion if its concentrates bulk handling facility in Callao, Lima. The company had also finished an expansion in December. Cormin expects to boost zinc trading by 15%. The company controls 75% of the lead concentrate exports in Peru. They mainly export to the U.S., Canada, Brazil, and Asia.[262] Canada's Western Copper holdings announced that it has put on hold plans of development of a zinc mine in Central Mexico because of low prices.[258] The low zinc prices also stalled the expansion of the Cajamarquilla refinery owned by Teck Cominco in Peru. The plant is expected to be closed from June through August.[259] In September, the restart was reported to be smooth and the plant was expected to have a normal month of production.[263]

The La Oroya smelter in central Peru, owned by Doe Run is investing $304 million in a modernization effort which is expected to last 10 years and is designed to meet international environmental standards.[264] Labor disputes at Grupo Mexico's plant at San Luis Potosi has stopped production as of Nov 3, 2002. The problem comes from rivalry among two unions.[265]

European market news.—Early in the year, Outokumpu, based in Ireland, announced that it has plans of restarting a 200,000 mt/yr mine (Tara zinc mine) and also plans on an expansion. However, the company said that an improvement in the market was needed before the company board would approve the expansion.[258] By June, the company announced that the restart had been pushed up and was expected to start in September and the company said that expectation were for the zinc market to improve.[255] In September, the company appeared to be on schedule to open in expectation of stronger demand in 2003, although it warned that another delay in recovery in prices would mean that necessary measures would need to be taken to adjust to costs.[266] The company also said that it will be closing operations at its plant in Kokkola, Finland, for the month of June due to weak demand.[267]

Porto Vesme, based in Sardinia, Italy, has requested the government to provide power at lower costs. The company has said that at current pricing the smelter cannot remain open. The government has agreed to look at all options to assist the plant.[261] The strike, which paralyzed the Belgian zinc smelter, Auby, owned by Umicore, ended in April. An agreement was reached whereby the bonus paid to employees would be less dependent on the price of zinc.[259] Umicore has also agreed to purchase GM metal, a zinc alloy processor and recycler based in Poitiers, France and is expected to add to Umicore's earnings in 2003. In addition, the company has also agreed to purchase outstanding shares of the Chinese company Fuhong.[268]

Metaleurop has decided to abandon production at its 90,000 mt/yr plant at Noyelles-Godault in France. Low zinc prices and high cost of production were stated as the causes. Expectations are that Glencore, which owns Metaleurop, will ramp up productions in other units to compensate for the loss at this plant.[269] The company also plans to sell its 135,000 mt/yr plant in Nordenham, Germany. The company expects the sale to help it get back to profitability, assuming markets conditions are favorable.[270] Swiss-based Xstrata plc's subsidiary, Asturiana de Zinc SA, will be acquiring the plant for $100 million. This would rise the production capability of Xstrata's zinc from 470,000 mt/yr to 600,000 mt/yr.[254]

Navan Mining announced that it had sold its copper-zinc mine, the Aguas Tenidas in southern Spain, to Ingenieria de Suelos y Explotacion de Recursos SA in November. The operation is currently suspended at the mine. Navan will receive royalty from future revenue for the sale. Navan was unable to find a buyer for its subsidiary Almagrera SA and hence the company has decided to close operations at the mine and processing plant.[265]

Asian and African market news.—The Sanli group, based in China, which had shut its ore processing plant in Dec 2001 due to power shortages, announced that it plans to reopen the plant by March.[258] Xiangfen Co, based in China, announced that weak prices has delayed its 50,000 mt/yr zinc line which was scheduled to be completed in August. In addition, Siding Lead-Zinc mine, in the Guangzi Zhuang Autonomous Region, has decided to delay its new 10,000 mt/yr zinc line which was scheduled to be completed late 2002 due to delay in equipment delivery.[263] The 35,000 mt/yr plant owned by Zhenzhou Changcheng Zinc was shut down in mid September on lack of funding. The company had been slated to be sold, but pricing problems have delayed the sale through November.[265] Dongling smelter will start work on a 100,000 mt/yr plant in the Shaanxi plant in march of 2003.[265]

Sterlite Industries, based in India, plans on increasing capacity at Hindustan Zinc Ltd., from 165,000 mt/yr to 300,000 mt/yr to meet growing demand. The company acquired Hindustan Zinc recently.[270]

Metorex has decided to delay the zinc project the company had planned for in Burkina Faso in central Africa. Weak prices for zinc was blamed for the delay. The development, if started, is expected to take 3-4 yr.[264]

Electric Power Industry

The energy sector has seen considerable upheaval in 2002 since the surprise announcement in Dec 2001 by Enron that it was filing for bankruptcy following a restating of its finances due to irregularities. 2002 saw the public unraveling of the extend of the irregularities with Arthur Andersen going under for its role in the cover-up, the suicide of a former Enron Vice-Chairman and the arrest of individuals connected to the case.[271] Since then, the Securities and Exchange Commission (SEC) has started an inquiry into Dynegy[272] and the state of California have accused five major power companies, AES-Williams, Duke Energy Corp., Dynegy Inc., Mirant Corp., and Reliant Resources Inc of price gouging during the energy crisis that hit the state in 2001.[273] While these had no apparent impact on prices for the consumers, the Bush administrations push for regime change in Iraq, coupled with a general strike in Venezuela did result in increases in crude oil prices with consumers paying more at the pump by the end of 2002.[274] Overall the price of electricity remained the same as in 2001. Prices, which fell every year from 1993 to 1999, reversed trend in 2000 and 2001.

The U.S. is the world's largest energy producer and consumer. It is a net energy importer and ranks twelfth in reserves of oil, sixth in natural gas and first in coal.[275] The G8 countries (comprising U.S., Canada, Italy, Germany, France, Britain, Japan, and Russia) account for 70% of the world economic activity and consume 60% of the world energy. The countries produce and consume 56% of the world's electricity, 43% of its coal, 68% of its natural gas and 72% of the world's nuclear energy.[276]

In the U.S., electricity demand was expected to be up 2.2% by the end of 2002 compared to 2001, mainly due to a hotter summer and higher cooling demand. The electricity generation in the first half of 2002 remained the same as that in 2001 at roughly 1,836 billion kwh with 1,235 billion kwh for utilities and 600 for nonutilities. 50% of the produced energy comes from coal-fired plants, 21% from nuclear, 17% from natural gas, 8% from hydroelectric, 3% from renewables, and 2% from petroleum. In recent years natural gas plants have started gaining more prominence because of the high capital costs of coal-fired plants, which makes them unattractive. Although there is growth in the nuclear sector, this is estimated to be much lower than that for natural gas.[275]

The country is estimated to have consumed 19.7 million barrels oil per day (MMBD) in 2002, consisting of 45% motor gasoline, 24% other oils, 19% distillate fuel oil, 8% jet fuel, and 3% residual fuel oil. Owing to the Sept 11, 2001 terrorist attacks jet fuel demand was down 6% for the first 9 months of 2002 compared to 2001. The country imported 11.2 MMBD oil (gross) until September 2002, representing 57% of oil demand. Two-fifths of this comes from OPEC countries and one-fifth from counties in the Persian gulf.[275]

Natural gas demand for the first half of 2002 declined by 5.2%, compared to 2001 mainly due to weather effects in residential and

commercial sectors. Expectations were that weakness in the industrial sector would result in little increase by the end of the year. The U.S. imports natural gas from Canada, and to some extent from Trinidad, Algeria, and Qatar. Expectations are that Mexico will become a significant source for this fuel and plans have been announced for the building of a pipeline connecting the two countries.[275]

Coal production in 2002 decreased to 1,089 million st from 1,121 Mmst in 2001. While coal remains the main source of energy production, because of cost advantages compared to oil and natural gas, exports have fallen since 1995 because of competition from Australia, South Africa, China, Venezuela, and Columbia.[275]

World news.—The European energy industry has been struggling since the collapse of Enron in late 2001. The increased scrutiny of the SEC on U.S. companies has resulted in many of them either leaving or scaling back operations in Europe significantly. The move was aimed at decreasing the workforce and reducing debts. This has resulted in consolidation among plants in Europe. However the future of the energy security in the continent remains in doubt.[277]

Asia is expected to see significant increase in energy demand in the coming decades with some countries predicting a doubling or tripling in demand. This follows a trend continuing since the economic slowdown in 1997 where a surge was seen in most countries, except in Japan. It is thought that Asia would account for a large part of global power capacity, offering immense opportunities to investors.[278]

Batteries

Batteries remained the mainstream source of power for systems ranging from mobile phones and personal digital assistants (PDAs) to electric and hybrid electric vehicles. The rechargeable battery market, estimated to be in the $6.8 billion range worldwide in 2000, is expected to increase to $9.4 billion by 2005.[279] Continuing on a trend over the previous years, lithium-ion cells increased its share in the secondary battery market with the establishment of numerous new manufacturing facilities, especially in the Far East. However, present trends suggest that fuel cells will threaten the battery market in a variety of applications in the years to come. While the situation is far from clear at this time, the scrapping of the Partnership for a New Generation Vehicles (PNGV) by the Bush administration, announced in Jan 2002, and its replacement by a fuel cell program,[280] appears to be another step in the direction of increased interest and funding towards the development of fuel cells. However, as noted in a panel on hybrid vehicles at the Society of Automotive Engineers Congress, hybrids are a precondition for fuel cell advancement and the two technologies are on converging paths,[281] suggesting that batteries would continue to be the subject of interest and innovation.

Lithium secondary batteries.—The lithium-ion battery market is expected to be more than 1.2 billion by 2005. Tremendous progress has been made in this field, with as much as a two-fold increase in the volumetric and gravimetric energy density for both 18650 and prismatic cells between 1994 and 2002, according to TIAX LLC, (shown in Fig. 9 and 10). While the 18650 market has been driven by the needs of the notebook computer industry, the increases in the prismatic cells are due to demand from the mobile phone market.[282]

Many companies have expanded production in 2002 to meet the increasing demand with monthly production estimated to be 100 million units a month, up from 75.5 million in 2001. The demand for lithium batteries is thought to have grown by 30% because of the mobile phone market. This has led to numerous expansions and the startup of new production facilities in 2002. While LG Chem of Korea expects to double production to 7 million batteries a month, Sony plans a 30% increase in its plants in Japan, Mexico, and China. Later in the year, Samsung SDI Co., and SKC Co. Ltd, both based in Korea, announced that they will be increasing production. While Samsung will be catering to the mobile phone market, SKC has won a contract from the U.S. Department of Defense to develop lithium-polymer batteries. In addition, Rickbery Industrial Inc (Hong Kong)

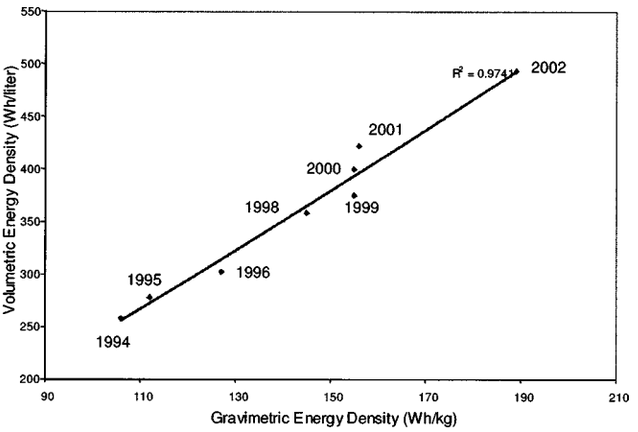

Figure 9. Gravimetric *vs.* volumetric energy density for 18650 Li-ion cells. The figure shows the increase in energy density spanning the last 8 years. (Reproduced from Ref. 282 with the permission of the author.)

and Hitachi Group (Japan) were planning on increasing their capacity in 2002.[283] Similarly, Tianjin Lishen Battery Joint Stock Co. Ltd. announced that it had completed expansion of its facility from 15 M pieces to 50 M pieces. The company mainly caters to the cell phone, laptop, and digital camera markets.[314]

The China International Trust and Investment Corp Guoan Group announced that it has built a battery production facility, Monguli Power Technology Co, in Beijing. The plant will manufacture Li-ion cells for motive as well as other specific applications.[284] In addition, Hitachi Maxell Ltd., announced that it will begin producing lithium-ion cells in Jiangsu province in China. The batteries, slated for the mobile phone and PDA market, will be exported to Japan, Europe and to the U.S.[285] Finally, Aucma, a leading Chinese household appliance producer, announced that it would start production at a new lithium battery manufacturing facility at Shandong province. The facility, which has a capacity of 30 million units/yr, would produce 45 types of batteries for various applications.[286]

Sanyo Electric Company, Japan, announced that it will be buying 51% of outstanding shares in GS-Melcotec Co., a subsidiary of Japan Storage. The two companies hope that this merger would increase the speed of technology development and cement their position as the world's biggest Li battery manufacturer.[295] Melcotec started producing batteries in the middle of the year in its facility in China.[287]

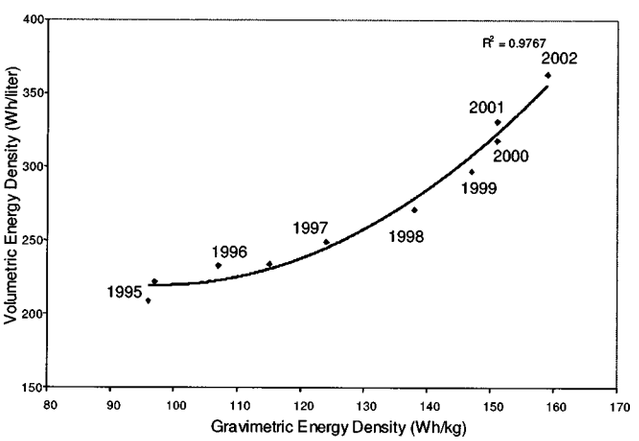

Figure 10. Gravimetric *vs.* volumetric energy density for prismatic Li-ion cells. The figure shows the increase in energy density spanning the last 8 years. (Reproduced from Ref. 282 with the permission of the author.)

Ultralife, manufacturers of both primary and secondary Li batteries, based in New York, announced an expansion of its current production capacity by the end of 2002. The company has been awarded contracts from the Army Communication and Electronics Command and the Department of Justice exceeding $3 million, in addition to a $4.5 million, 5-year, contract from the UK Ministry of Defense, which have spurred the expansion.[288] The company has also increased its product line with the introduction of two prismatic cells for the mobile phone and PDA markets. The cells will be manufactured at Ultralife Taiwan Inc.[289]

AVESTOR, co-owned by Hydro-Québec and Kerr-McGee Chemical LLC, has started production of a lithium-metal-polymer battery in their plant near Québec. At present, the company hopes to use these batteries to provide backup for telecommunications relay equipment.[290] The battery, which uses a metallic foil anode, is attractive because of its high volumetric and gravimetric energy density.[291]

Lithium Technology Corp. (LTC), in PA, has signed a Letter-of-Intent with German Li-polymer battery company GAIA for a proposed merger. Under the agreement GAIA will become a wholly owned subsidiary of LTC. The two companies have an order to deliver prototype 42 V and HEV batteries for a major automobile manufacturer in the first quarter of 2002. The new development includes termination of an existing merger agreement with Ilion Technology Corp.[292,293] The 42 V systems are expected to provide better fuel efficiency, reduce emissions and provide more electronics and features in the car.[294] In November, LTC signed a share-exchange agreement that gives it a 60% interest in GAIA.[295] The company also shipped prototype 42 V, 7 to 8 kW lithium batteries to BMW in November, under the Astor program (assessment and testing of advanced storage systems for propulsion and other electrical systems in passenger cars).[296]

Lithium battery manufacturer Solid Energy GmbH, Germany, has started manufacturing lithium-polymer batteries using solid-state conductors at its plant in Germany. The process uses a patented paste production method developed by Fraunhofer-Gesellschaft and licensed to Solid Energy.[297]

FMC Lithium and Altair Nanotechnolohies Inc. have signed an agreement to develop nano-lithium titanate spinel for use in primary and secondary batteries. The new material merges FMC's lithium experience and Altair's proprietary nanotechnology expertise. The company said that testing showed that this material had an order of magnitude higher power capability compared to conventional batteries and that it had the unique property of being useful as an anode in rechargeable and as a cathode in primary cells.[285,298] FMC also forged an alliance with AEA Battery systems, Scotland, to develop new lithium batteries for cell phones, laptops and PDAs.[296]

The Université de Montréal is spinning off a new company, Phostech Lithium Inc., which is expected to produce Li-ion cells based on phosphate-based materials. The company has setup a manufacturing process to produce samples for potential users, and is expected to start production in early 2003.[299] The cost advantage of phosphate based cathodes has also led Valence Technology, TX, to replace cobalt from their cells. Valence announced that it expects the new batteries to hit the market in spring.[300] Iron phosphate was also the material of choice for Electrovaya, based in Canada, which released the PowerPad series aimed at the notebook computer market.[301]

Moltech Corp. has changed its name to SION Power Corp. The new name is said to emphasize the company's objective of using sulfur based lithium batteries for the electronics market.[302]

Other rechargeable batteries.—The European Commission, in its End of Life Vehicle Directive, had restricted the use of mercury, cadmium, and lead in certain types of vehicles starting from July 2003. However, in May 2002, the Commission proposed the addition of nickel-cadmium batteries for electric vehicles in its exemption list. This proposal reflects the belief that these batteries are critical for the electric vehicle market.[303]

TWD Battery Co., LTD, based in China has entered into a royalty-bearing nonexclusive license agreement with Michigan based Ovonics for their nickel metal hydride cells. The agreement would allow TWD to make, use and sell consumer batteries with rights to sublicense affiliates of TWD.[290] Texaco Ovonic Battery Systems, a joint venture between ChevronTexaco Technology Ventures and Ovionics Battery Co. Inc, has been awarded a two-year $5.2 million contract to develop Ni-MH cells as part of the FreedomCar initiative. The program will result in the delivery of a 35 kW battery pack system including the thermal management, control electronics and battery management systems.[304] Texaco Ovonics is building a multimillion dollar production facility in Springboro, Ohio. The new plant will replace an older plant in Kettering and is expected to start production of Ni-MH cells in April 2003.[305]

Sanyo Electric Co. and Honda Motor Co., both from Japan, announced that they will be working jointly to develop nickel-hydrogen batteries for hybrid vehicles. Honda, which presently uses Panasonic batteries for its HEVs, hopes to use the new batteries in 2 to 3 years. Sanyo also has an agreement with Ford Motor Co. to supply batteries for its hybrid cars.[306]

Varta, based in Germany, has sold its automotive lead-acid battery division to Johnson Controls, Inc, WI for $303 million. This will give Johnson Controls a market leadership position in Europe and America.[307] Johnson Controls has also signed an agreement with C&D Technologies (PA) to be the primary distributor of OPTIMA spiral packs for motive and standby power and the Spiral-cell Technology batteries.[312] The Royal Automobile association of Australia has selected Exide (PA), to be its exclusive lead-acid battery supplier. The five-year agreement is expected to result in more than $A12 million in sales.[308]

Energy Visions Inc (EVI) has agreed to acquire 51% stake in Pure Energy Inc (PEI). EVI hopes to adapt PEI s Amherst, Nova Scotia, plant, which presently manufactures rechargeable alkaline cells, to also manufacturer EVI's proprietary nickel-zinc batteries. The company said that the plant had capacity to meet needs for both products for several years.[309]

AER Energy, based in Georgia, has granted Rayovac Corp., license rights for its zinc-air battery technology. The two companies have completed a technical feasibility phase of the license and development agreement.[292]

Primary batteries.—Duracell, CT, has teamed up with IXI Mobile to provide primary zinc-air cells for IXI's low-cost wireless device solutions that bridge cellular networks to personal cellular networks. The product is expected late 2002. The low cost of the cells is expected to be the driver for the market.[310]

Rayovac, WI, and Varta, Germany, have signed an agreement to combine Varta's global consumer battery business with Rayovac's. This does not include Varta's Brazilian joint venture, its automotive, or its micro-power battery businesses. Rayovac will acquire all of Varta's business outside of Germany and will become majority partner in a new joint venture that will conduct all consumer battery operations in Germany. The acquisition will make Rayovac the number-two battery company in Europe, a stronger number one position in Latin America (excluding Brazil) as well as a leading brand[311] in North America below Energizer and Duracell.

Toshiba Battery Co. has launched a new primary cell based on the nickel-zinc technology for use in digital cameras. The battery promises 17 times longer life and better high power capabilities compared to conventional alkaline cells.[312] Panasonic (a division of Matsushita) has also developed a nickel-zinc system for the same application.[313]

Saft, a leader in providing primary batteries for the U.S. military, received a $16 million contract to supply primary lithium manganese oxide cells to the Army over the next five years. This is in addition to a $150 million contract to supply lithium sulfur dioxide cells which it received earlier in 2002. The company's plant in North Carolina is expected to assemble the cells with components manufactured in its facility in the UK.[314]

Electric and hybrid electric vehicles.—2002 saw the concept of the hybrid electric vehicle gain mainstream acceptance in the American market. While environmental issues and the need for energy security are spurring the market, the weakened economy has resulted in less purchasing power for the consumer.[315] However, the concept of the EV seems to be seeing a decline with Ford deciding to stop sales of its Th!nk vehicles and recent news in 2003 that Toyota has decided to stop sales of its RAV 4 electric, after announcing that they would be restarting sales in late 2001-early 2002,[316] and GM discontinuing the EV1. However, this concept seems to be gaining ground for small transportation vehicles with limited range, electric bikes, and water scooters. The concept of a fuel cell vehicle (FCV) has gained enormous popularity in recent years and these can also be termed electric vehicles. However, this section will only summarize the battery-powered-vehicle sector. FCVs are covered in the Fuel Cells section of this report.

In late March, Honda's new Hybrid Civic models reached dealerships in the U.S. EPA city/highway fuel economy ratings for the vehicle are 46/51 for the 5 speed and 48/47 for the vehicle with a continuously variable automatic transmission. The company expects sales to average 2,000 vehicles/year.[317]

The Toyota Prius was certified by the U.S. Internal Revenue Service to be eligible for a $2,000 clean-burning fuel tax deduction. The company has sold more than 30,000 cars (until Nov 2002) in the U.S. since it was unveiled in July 2000 with more than 100,000 cars sold worldwide.[318] Toyota, in addition to its Prius hybrid, plans on offering a hybrid version of the Estima minivan and its Crown luxury car.[319] Toyota, unlike Honda, says that they are making a profit on their vehicles.[317] The Honda Insight and Civic hybrids, were also expected to receive tax credits.[320]

The High-Mobility Multipurpose Wheeled Vehicle (HMMWV), popularly called the Humvee, is slated to be converted to a hybrid. AM General Corp. is developing the hybrid version based on the needs of the Army, which requires its vehicles to run on both fuel and electricity. The new vehicle is expected to consume 30% less fuel, be transportable abroad a C-130 aircraft, provide continuous auxiliary power, and operate silently.[321] This project is in keeping with the Army's goal of using hybrid technology to enhance the fuel efficiency of their vehicles.[322]

The Ford Motor Co., based in MI, unveiled its Focus FCV hybrid vehicle that uses a battery pack along with a hydrogen fuel cell. Five vehicles are expected to be made this year for testing with the company claiming that production will start in 2004. Ford also expects to release a hybrid version of the Ford Escape, which uses a gasoline engine, in 2003.[323] Exide has been selected to provide 12 V lead-acid batteries for the FCV.[324] However, the company has decided to stop selling its Th!nk electric vehicle in the U.S. at the end of 2002 because of poor sales. This was a turnaround from earlier in the year when the company had embarked on a demonstration project for the vehicle.[325] The company said that it may also end European production. The company sold 1,600 of its Th!nk Neighbor and donated 500 to national parks, and sold 1,000 of the Th!nk City.[326] Voltage Vehicles, a subsidiary of ZAP, an electric carmaker based in CA, had in December made an offer to buy Th!nks electric vehicle assets. Reports suggest that the ZAP shareholders are overwhelming in support of the acquisition.[327]

Fuji Heavy Industries, partly owned by GM, announced in late 2001 that it would be bringing out a hybrid version of its Subaru car brand. The company expects a 10% improvement in fuel consumption.[328] No information is available as to possible times for the car to reach the market.

China appears to be entering the electric car market with Beijing Jiajie Boda Electric Vehicle Co. and the Hubei Dongfeng Electric Vehicle Co. making electric cars. In September, the Mingua Group, based in Shenzhen China, has developed an electric vehicle running on lithium-ion cells. The car is reported to have a range of 300 km (186 miles) and maximum speed of 120 kph (75 mph). In addition, the Chinese Ministry of Science and Technology also announced plans to develop electric vehicles with the government investing RMB 1 billion ($0.12 billion) in the project.[329]

eMotion Mobility, based in GA, plans to build a plant for the production of electric vehicles. The company is partnering with Micro Compact Car, a wholly owned subsidiary of Daimler Chrysler. Micro will build the cars in France and then ship them to emotion, which would then retrofit the vehicles with an electric drive train. The company plans to start production by September. The cars will have a maximum speed of 70 mph.[330] eMotion has also signed an exclusive strategic agreement with Metro Atlanta Regional Transport Authority to develop a station car program whereby rail users will have access to cars parked at stations.[331]

Enax Inc. has developed a one person minicar powered by its large Li-ion batteries. The car can travel 150 km (93 miles) on a eight-hour charge and has a maximum speed of 30 kph (19 mph).[332] Japanese toy maker, Takara Co., will market a one-seater electric car with a range of 80 km (50 miles) with a maximum speed of 60 kph (37 mph). Two models, one reminiscent of classic cars and the other a sports car, are being offered.[333] Montreal based SLP Canada has also entered the small, eco-friendly vehicle market with a three-wheeled, one-driver vehicle. The company recently signed a five-year contract to build three microvehicles for Corbin Motors, CA.[334] Famed Italian sports car manufacturer, Lamborghini, has entered the EV business with a Neighborhood Electric Vehicle, or NEV. The golf carts use Trojan deep cycle lead-acid batteries.[335] Automotive legend, Lee Iacocca, has also entered the NEV market with the battery powered Lido which has a top speed of 25 mph and a 40 mile range per charge.[321]

BAE Systems Controls, based in VA, will develop a prototype hybrid electric truck for FedEx and is expected to be delivered in September. The trucks will use a diesel engine along with BAE Systems HybriDrive propulsion system.[336]

The electric bus appears to be gaining prominence with a world market of more than 17,000 buses per year. The U.S. market is thought to be 2,500 buses a year with more than 30,040 buses already in service. The American Public Transportation Association says that electric buses have better acceleration compared to their internal combustion counterparts, making them attractive.[337]

The Japanese government has set regulations for NO_x and particulate matter (PM) emissions for the medium and heavy-duty vehicle manufacturers. In 2003, the first stage in this regulation will mandate the reduction of NO_x to 3.38 g/kW and PM to 0.18 g/kW. In the second stage, NO_x will be mandated to reduce to 2.0 g/kW and PM to 0.027 g/kW by 2005. This has led truck makers to look to hybrid technology to meet these goals. Mitsubishi, Nissan, and Hino Motors (part of the Toyota group) are all in the process of trying various hybrids with electrical power from either batteries or capacitors.[338]

Electric bikes are a growing market with estimates that 30,000 were sold in the U.S., 70,000 in Europe, 200,000 in Japan and 300,000 in China in 2001. The maintenance free nature of this vehicle, along with its low cost has spurred the market. Panasonic is entering this area with the introduction of a pedal-activated, effort-sensing bike that matches the effort of the rider. Using nickel cadmium batteries the 40 lb bike can reach speeds of 15 mph.[330] Power Technology, based in Nevada, hopes to enter this market with the development of an energy package. The company has forged an alliance with Key Capital Group in this venture. This package is expected to use Power's lead-acid batteries along with its Accelerate Charger technology.[339] China, with expected sales over 1 million in 2002, is expected to replace Japan as the number one producer of electric bikes.[340]

ZAP, based in CA, has developed a personal water propeller that is capable of pulling swimmers, snorkelers, and scuba divers through water at speeds of 2 mph for more than 1 h. The Sea-Doo Seascooter will be marketed by Daka Development.[341] In October ZAP merged operations with Voltage Vehicles and the RAP Group Inc., both based in CA.[342]

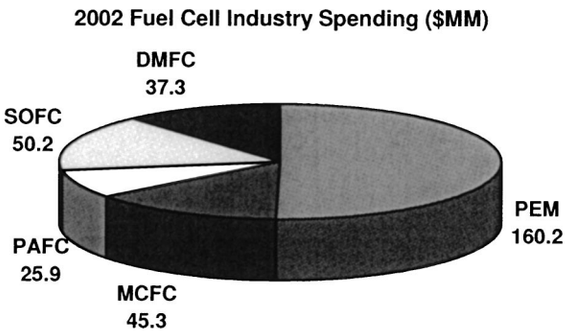

Figure 11. Spending in 2002 by fuel cell type, as estimated by BCC in April 2002.[347]

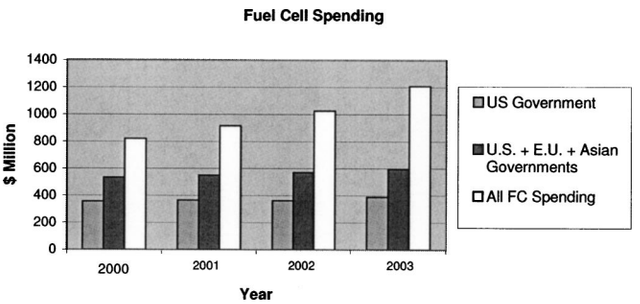

Figure 12. Actual (2000-2001) and estimated (2002-2003) fuel cell spending by US, European Union, and Asian governments and over 800 companies. Spending includes PEM, PAFC, MCFC, SOFC, DMFC, metal air, hydrogen storage, and reforming. Source: BCC.[347]

The world's first electric powered liquefied natural gas (LNG) vehicle was unveiled by Samsung Heavy Industries. The system replaces traditional steam turbines in ships and is thought to be targeted towards higher value vessels like LNG carriers. The system promises energy saving while increasing cargo capacity.[343]

RailPower Technologies, a Canadian locomotive company, has introduced a new shunter that is powered by lead-acid batteries, named the Green Goat. A 85% reduction in smog causing nitrogen oxide and particulate matter is expected from these new engines in addition to reducing costs by 30%. This reduction in cost is mainly due to the less usage of diesel fuel. At present only one shunter is in operation.[344]

Fuel Cells

2002 has seen a further increase in interest and activity in the fuel cell world. Widespread interest is reflected by the fact that a large number of universities in the U.S. now have a fuel cell program, and many companies in the energy, chemicals, vehicle, and components sectors have started their own fuel cell efforts in an attempt to capture a part of this potentially huge market. We are in a very interesting stage of fuel cell development, where acceptance for the technology is growing, but further fundamental and applied R&D is needed to overcome lifetime and cost hurdles. As the U.S. government has incorporated fuel cells and a hydrogen economy into its long-term plan, it is also making more funding available. However, the environment for obtaining money for fuel cell research has changed, with further funding dependent on producing results, not just promises.[345] The environmental benefits of fuel cells are well known, but commercial success ultimately hinges on practical issues such as cost, reliability, and longevity. Fuel cells for portable electronics and stationary power are expected to appear first in the market. A mass market for fuel cells is likely to develop in Europe and Asia before taking hold in the U.S. Environmental regulations are stricter and energy prices higher in Europe, providing an inherent advantage to introduction and acceptance of fuel cell technology.[345,346]

While a hydrogen economy has been discussed for decades, until recently it seemed unlikely to happen due to technological, economic, and political hurdles. However, in February 2002, the U.S. Department of Energy released a document entitled Toward a More Secure and Cleaner Energy Future for America: A National Vision of America's Transition to a Hydrogen Economy to 2030 and Beyond. It will be used as a foundation for formulating the elements of a National Hydrogen Energy Roadmap. The document sees hydrogen as a long-term solution to America s energy needs, with near-term possibilities.

The main fuel cell types are proton exchange membrane (PEM, also called polymer electrolyte membrane), direct methanol (DMFC, an important sub-group of PEM), alkaline (AFC), phosphoric acid (PAFC), molten carbonate (MCFC), and solid oxide (SOFC). Figure 11 shows 2002 spending of the fuel cell industry by fuel cell type, as estimated by the Business Communications Corporation (BCC) in April 2002.[347] About half of the total spending was on PEM, reflecting the multitude of companies and institutions involved in this effort. Figure 12 shows the spending trend based on the same BCC report,[347] which considers its estimates conservative. The annual average growth rate (including government spending) is about 9%. Measured without contributions from governments, growth in the hydrogen fuel cell market is projected to be roughly 22% over the next five years. Revenues to fuel cell companies are expected to replace government research grants. By 2007, the global hydrogen fuel cell market is expected to be over $1 billion, which includes hydrogen storage technologies. If all government spending is included in the figure for 2007, the total fuel cell spending will be about $1.8 billion, according to BCC.

One of the hurdles towards commercialization of fuel cells has been the lack of codes and standards to cover the installation and operation of fuel cells, including alternative fuel infrastructure, refueling, and grid interconnection. User preferences in this industry are shaped by relevant federal, state, and local government regulations and by relevant standards and certification requirements. These requirements often indicate what test and evaluation procedures will speed market acceptance. A number of organizations, such as the Society of Automotive Engineers (SAE), International Organization for Standards (ISO), International Electrotechnical Commission (IEC), National Fire Protection Association (NFPA), Underwriters Laboratories (UL), American National Standards Institute (ANSI), ASME International (American Society of Mechanical Engineers) and the Institute of Electrical and Electronics Engineers (IEEE) are involved in creating such standards, with significant progress made during 2002. The U.S. Fuel Cell Council is an industry association dedicated to fostering the commercialization of fuel cells in the United States. Members include fuel cell developers, manufacturers, suppliers and customers from all over the world. The Fuel Cell Council is actively working with its members and the above mentioned organizations to develop standards for materials and test protocols and to speed up the development of codes and standards. It is also active in educational outreach and works to raise public awareness of fuel cells and their potential.

Fuel cells for stationary power.—Distributed generation generally is defined as electric generation under 50 MW sited close to the load it serves. However, the majority of systems installed are rated less than 10 MW.[348] The distributed generation market is expected to reach $4-10 billion by 2010 according to Reed Wasden Research, of which fuel cell companies are hoping to capture a significant share.[345] According to Robert Lorand of Science Applications International Corporation, distributed generation represents approximately five percent of the current electric generating capacity in the U.S. For the period 2005 through 2015 the potential market for distributed generation is forecast to range from a low of 10,000 to a high of 16,000 MW.[349] Allied Business Intelligence Inc. (ABI) released a study in October 2002 estimating the global distributed

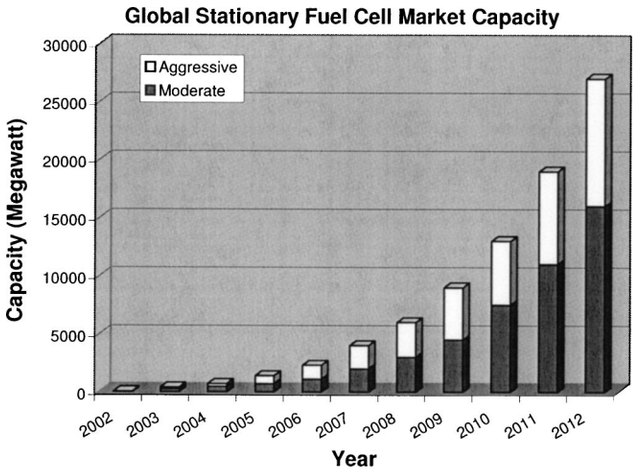

Figure 13. Projected global stationary fuel cell market capacity. Source: Allied Business Intelligence Inc.[351]

generation market to increase steadily from about 40 GW in 2002 to 300 GW by 2011.[350] This has the potential to increase the reliability and quality of worldwide power.[350] Fuel cells are expected to gain an increasing share of this market, competing against technologies such as reciprocating engines, small gas turbines and wind turbines. A November 2002 study by ABI, shown in Fig. 13, forecasts an expansion of the global fuel cell stationary energy generating capacity from 45 MW in 2002 to 16,000 MW by 2012 according to a moderate estimate and to about 27,000 MW for an aggressive estimate.[351] That would mean a fuel cell share of 4-5% of the total distributed generation market by 2011, up from 0.1% in 2002. One of the best markets for distributed generation is expected to be in areas such as Silicon Valley, where companies have a need for high reliability and quality of supply.[347] Consequently, quality power and industrial power supply markets are expected to see higher growth rates than residential markets, with early adopter markets in wastewater treatment plants, telecommunication back up centers, and data centers.[351] Distributed generation will also find a market in areas where the cost of retail electricity and transmission and distribution are high, and where the co-generated heat is a valuable resource. Utility companies are interested in using fuel cells to power remote facilities; the need to build additional power lines could be avoided, saving hundreds of thousands of dollars. In remote applications without access to natural gas, stationary fuel cells could operate on a variety of primary fuels including propane, methanol or other alcohols, diesel or other distillate fuels and synthetic fuels, such as dimethyl ether.[352] A report by the market research firm Frost and Sullivan projects the North American stationary fuel cell market will grow at a compounded annual growth rate of 49.6 percent by 2005. The European fuel cell market is expected to reach $42 million by 2008, with revenues reaching $16.3 billion by 2020 and $45.8 billion by 2040.[347]

The U.S. is growing increasingly more dependent on electricity. In 1970, electricity use accounted for 25% of the energy consumed in the country. In 2001, that figure was 40%, and the upward trend is expected to continue. The demand for distributed generation also is increasing. In 1989, the U.S. DOE estimated that 10% of the nation's commercial floor space was served by on-site generators. But by 1995, the last time the data were compiled, this figure had more than doubled, reaching 23%. In 2002 a major barrier hindering integration of distributed generation with electric power grids was addressed. The Institute of Electrical and Electronics Engineers (IEEE) has approved a standard for interconnecting distributed and dispersed generation facilities. The long-awaited standard has been under development for more than four years.[353]

The stationary power market consists of residential (typically 1-5 kW) and commercial/industrial (hundreds of kW to MW) applications. Different fuel cell manufacturers are targeting one or both of these markets. PEM fuel cells appear to be the leading technology candidates for residential use due to their low-temperature operation and high power density, while MCFCs and SOFCs are advantageous for the larger loads. SOFC have also been proposed for 1-100 kW size applications. The Solid State Energy Conversion Alliance (SECA), which was established by U.S. DOE in 1999, provides funding to commercial developers, universities, government agencies and national laboratories to develop SOFCs with a targeted factory cost of less than $400 per kilowatt by 2010.[354]

Fuel cells for transportation.—In early January 2002, the Bush administration announced plans to foster the development of hydrogen-powered fuel cell vehicles with the program Freedom Cooperative Automotive Research, or FreedomCAR.[355,356] This program replaces the Clinton-era Partnership for a New Generation of Vehicles (PNGV), which was established in 1993 to help automakers design an 80 mpg mid-sized sedan. Most of the estimated $150 million that the DOE will put into FreedomCAR will be used to fund research at universities and national laboratories to develop more efficient and durable fuel cells.

The world's leading automakers are in a race to bring fuel cell vehicles (FCVs) to the marketplace. FCVs will be two to three times more efficient than a gasoline internal combustion engine. About 60 million new cars are sold worldwide each year. Automotive industry leaders have speculated that fuel cell vehicles could account for 20-25 percent of new car sales within the next 20-25 years, a potential market of 12-15 million vehicles each year. To date, more than 50 vehicles have been demonstrated using fuel cell technology. Every major automaker is looking at fuel cells either for powering vehicle propulsion, or for supplying electricity for non-propulsion power needs such as lights and air conditioning. The first commercial fuel cell vehicle sales are expected as early as 2003-2007. Full commercialization will probably come by the end of the decade.[357] Allied Business Intelligence estimated in December 2002 that the number of worldwide fuel cell vehicles will reach 800,000 by 2012.[358]

Table I gives an overview of fuel cell powered vehicles presented by the major car manufacturers during 2002.[359] These vehicles are designed to demonstrate the feasibility of fuel cells as an efficient and low-emission power source, and to gain experience building fuel cell systems for cars, which have tough requirements (rapid start-up, heat dissipation, rugged and compact design, $>$5000 h life). PEM fuel cells are found under the hood of most prototype fuel cell cars and buses. Many vehicles, classified as hybrids, use advanced batteries or supercapacitors to meet peak demand while keeping the fuel cells as small as possible. It is noteworthy that all vehicles released in 2002 are powered by hydrogen, which is carried on board as a compressed gas with pressures up to 10,000 psi. Depending on tank size and fuel consumption, a driving range of $>$200 miles has been achieved. This seems to reflect the ready acceptance by car manufacturers of a push towards building a hydrogen infrastructure. Many concept vehicles released in previous years used methanol or gasoline as a fuel source, in combination with an onboard fuel reformer.

Fuel cells are also being designed for other vehicles, such as scooters, bicycles, lawnmowers, and heavy commercial vehicles such as buses, trucks, and locomotives. Fuel options under consideration include hydrogen, methanol, natural gas, gasoline, diesel, and sodium borohydride.

At least eight hydrogen fueling station were opened in 2002, among which two are in the U.S., four in Japan and two in Europe; many more are planned to open in the near future in support of hydrogen fuel cell vehicle demonstrations.[360] The hydrogen is made available as compressed gas and/or liquid, using a number of different generation methods, including water electrolysis and hydrocarbon reformation.

Table I. Fuel cell powered prototype vehicles (except where noted) first shown in the year 2002. All vehicles use compressed hydrogen gas.

Manufacturer	Model	Engine Type	FC rating/manuf	Range (miles)	Top Speed (mph)
Daimler-Chrysler	F-Cell (A-class)	FC/battery hybrid	85 kW Ballard	90	87
Ford	Advanced Focus FCV	FC/battery hybrid	85 kW Ballard	180	N/A
General Motors	Advanced HydroGen3 (Zefira van)	FC	94 kW GM	170	100
General Motors	Hy-Wire Proof-of-Concept	FC	94 kW GM	80	97
Honda	FCX (limited production)	FC/capacitor hybrid	85 kW Ballard	220	93
Nissan	X-Trail (SUV)	FC/battery hybrid	75 kW UTC Fuel Cells	N/A	78
Toyota	FCHV High-lander SUV (limited production)	FC/battery hybrid	90 kW Toyota	180	96
Volkswagen	HyPower	FC/capacitor hybrid	40 kW Paul Scherrer Institute	94	N/A

Source: Fuel Cells 2000.[359]

The Japanese Ministry of Land, Infrastructure and Transport in September finalized a policy of making fuel cell-powered cars, which Japanese car makers were expected to be the first in the world to release onto the market in 2002, exempt from the automobile acquisition tax and automobile tax for a period of two years from 2003. The tax reductions already applied to hybrid vehicles and other low-emission vehicles have been extended by two years, and the eligibility of these measures will be expanded to include LPG vehicles and ultra-low particulate matter vehicles.[361] Commencing in 2002, the Ministry of Economics, Trade & Industry (METI) also has initiated a three-year fuel cell validation project for 12 residential fuel cells from six different companies in the 1-5 kW range.[362,363] In a PEM fuel cell, the membrane electrode assembly, which consists of the anode, cathode, membrane and gas diffusion layers, constitutes more than 80% of the fuel cell stack cost. In turn, the fuel cell stack represents two-thirds of the system cost of a PEM fuel cell with fuel reformer, according to a study by Arthur D. Little commissioned by DOE's Office of Advanced Automotive Technologies released in April 2002.[364] The DOE goal is to bring the system cost down (including a reformer) to about $2,500 per vehicle.[347] Platinum accounts for about 20 percent of the total cost of a 50 kW PEM fuel cell system for vehicles, according to the Business Communications Corporation (BCC). The system requires about 200 grams of platinum and about 45 grams of ruthenium. The estimate is based on platinum loading in the fuel cell's membrane electrode assemblies (MEA) of 0.8 milligrams per square centimeter. The fuel processor requires about 18 grams of platinum and the fuel cell's MEA about 182 grams. Researchers have proven that a similar performance can be obtained from the fuel cell with platinum loadings as low as 0.1 milligrams per square centimeter.[347]

GM's goal is to develop fuel cell powertrains for sale beginning in 2008 to fleet customers and 2010 for consumers, and to be the first automaker to sell one million fuel cell vehicles. The company showed a fuel cell concept car, named AUTOnomy, which uses fuel cells and drive-by-wire technology.[365] Propulsion and electrical systems are placed in the chassis, which would allow a variety of bodies to be docked to it. GM believes such a vehicle could be ready for the market by 2020.[355]

Japanese automakers Toyota and Honda released new fuel cell cars at the end of 2002. This represents a landmark achievement in the auto industry coming 100 years after the development of an automobile powered by an internal combustion engine by Daimler-Benz, which was itself preceded by the development of Watt's steam engine.[366] In December a ceremony was held at the Japanese Prime Minister's official residence to commemorate delivery of the world's first fuel cell cars, leased from Toyota Motor and Honda.[362] Also in December 2002, the first of five Honda FCX vehicles was delivered to the City of Los Angeles. It is leased by the city and will be used in normal, everyday use. Air Products and Chemicals, Inc. was contracted to provide the hydrogen fuel and refueling infrastructure.[367]

Nissan Motor Co. plans to begin limited marketing of fuel cell vehicles in Japan in 2003, two years ahead of its previously announced schedule. After receiving government approval, the automaker has begun public-road tests of its X-Trail FCV, a hydrogen-powered fuel cell sport-utility vehicle. In 2001, Nissan and Renault began a five-year joint fuel cell R&D project with a projected investment of 85 billion Yen. In that project, Nissan took the lead in researching hydrogen-powered fuel cells, while Renault studied vehicles equipped with an onboard reformer.[368]

DaimlerChrysler unveiled the Natrium minivan in December 2001, a prototype fuel cell vehicle that runs on sodium borohydride ($NaBH_4$), a naturally occurring substance used in laundry soaps. An onboard reformer, developed by Millennium Cell in NJ, partitions the hydrogen needed for the fuel cells (supplied by Ballard) and the used chemical slurry, which is then stored so it can be pumped off the vehicle and recycled.[369] It was tested by Car and Driver in 2002.[370] Exploring a different fuel option, DaimlerChrysler's NECAR 5 (which was first shown in 2000) runs on methanol. It completed the first cross-country trip in the US in June 2002.[371]

Ford's fuel cell vehicle, called Focus FCV, uses a Ballard fuel cell stack and hydrogen compressed to 5000 psi, in combination with a NiMH battery.[372] It was road tested in Europe late in 2002;[373] fleet availability is expected for 2004, according to the company.[374]

Hino Motors Ltd., a subsidiary of Toyota, showed and started road-testing the fuel cell bus FCHV-BUS2, an improved version of its FCHV-BUS1 shown a year earlier. The PEM fuel cell/NiMH battery hybrid powers its two 90 kW Toyota fuel cells from compressed hydrogen (5000 psi), has a range of 186 miles, 50 mph top speed and carries up to 60 passengers.[375,376]

SOFCs are being tested on cars and trucks with traditional powertrains as auxiliary power units (APU), allowing long-haul trucks to stop idling large diesel engines, and providing an array of benefits for today's electricity-hungry automobiles.[357] Much of this R&D is carried out under DOE's SECA program.[354,377] According to SAE

International, the average 18-wheel truck is on the road 303 days/yr, with an average idling time of 6 h/day.[378]

Other news.—In November 2002, Energy Secretary Spencer Abraham unveiled the National Hydrogen Energy Roadmap, a document designed to ensure a more secure and cleaner energy future for America. The Roadmap provides a blueprint for the coordinated, long-term, public and private efforts required for hydrogen energy development.[379] These requirements include (*i*) improved fuel cell durability, (*ii*) decreased cost of fuel cell stack, (*iii*) decreased hydrogen production cost, (*iv*) enhanced infrastructure/vehicle systems integration, (*v*) focused demonstrations to showcase vehicle/infrastructure capabilities, (*vi*) accelerated development of codes and standards, and (*vii*) public policies to educate the public about hydrogen as a fuel.

To meet the goals of the project, stack durability of 2000 h, range of 250 miles, and \$3 per kg H_2 cost at station (on-or off-site production) for 2008 and 500 h, 300 miles, and \$1.5 per kg for 2015 were presented as targets to verify progress.

The EU has announced its commitment to achieving a hydrogen energy infrastructure, vowing to overtake the U.S. and Japan in the race to a hydrogen-based future. EU plans to spend \$2.09 billion between 2003 and 2006 on renewable energy development, mostly on technologies related to hydrogen. That's up from only \$124 million spent between 1999 and 2002.[380]

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